

1 A REAGENT SYSTEM AND METHOD FOR MODIFYING THE LUMINESCENCE OF
2 LANTHANIDE(III) MACROCYCLIC COMPLEXES

3 BACKGROUND OF THE INVENTION

4 To facilitate understanding of the composition and method of this invention, the following
5 definitions of terms used throughout this specification and claims are provided.

6 1. The term "equivalent(s)" is used in the chemical sense to describe a quantity of a specific
7 component of a molecule or of a specific ion of a salt. Thus a 1M solution of $GdCl_3$ would
8 contain 1 equivalent of the gadolinium ion and 3 equivalents of the chloride ion in 1 liter
9 of solution.

10 2. The term "light" is used to designate any form of electromagnetic radiation, including the
11 ultraviolet, visible, and infrared region of the spectrum.

12 3. The term "photon" is used to designate an individual particle of light.

13 4. The term "lanthanide" is used to designate any of the lanthanide elements (atomic number
14 57-71) as well as the lanthanide-like yttrium and the actinide elements (atomic number 89-
15 103).

16 5. The term "chemical compound" follows the common usage of the field of chemistry and
17 is used to describe any pure substance that is formed when atoms of two or more different
18 elements combine and create a new material that has a constant composition throughout
19 and properties that are unlike those of the constituent elements.
20
21

22 6. The term "complex" is used to describe any species in which a metal atom or ion is
23 bonded to an organic moiety. Examples of complexes include the lanthanide(III) macrocy-
24 cles of US Patents 5,373,093 and 5,696,240; the cryptates of US Patents 4,927,923,
25 5,162,508, and 5,534,622; the phthalamidyl-containing chelates of US Patent 6,515,113;
26 the salicylamidyl-containing chelates of US Patent 6,406,297; and the chelates formed
27 with the reaction product of diethylenetriaminepentaacetic acid dianhydride (DTPAA) and
28 p-aminosalicylic acid of US Patent 4,962,045. In such a complex, each bond between the
29 metal atom or ion and the organic moiety consists of a shared electron pair originally
30 belonging solely to the organic moiety. Since many complexes can be isolated or identi-
31 fied by standard techniques, they are chemical compounds.

- 1 7. The term "ligand" is used to describe the organic moiety of a complex.
- 2
- 3 8. The term "unidentate ligand" is used to describe a molecule or ion that binds to a metal
- 4 atom or ion through a single site, and more specifically through a single atom or a through
- 5 the electrons of one multiple bond between a pair of atoms.
- 6 9. The term "multidentate ligand" is used to describe a molecule or ion that can bind to a
- 7 metal atom or ion through two or more sites, and more specifically through two or more
- 8 atoms, or through the electrons of two or more multiple bonds between pairs of atoms, or
- 9 through a combination of thereof.
- 10 10. The term "eteroatom" is used to indicate any atom of a cyclic molecule or of a cyclic por-
- 11 tion of a molecule or ion, that is not carbon.
- 12
- 13 11. The term "macrocycle" is used to describe a cyclic organic compound in which the cycle
- 14 consists of nine or more members, including carbon and all eteroatoms with three or more
- 15 of such atoms capable of acting as electron pair donors (ligands) toward metal atoms or
- 16 ions.
- 17 12. The term "macrocyclic ligand" is used to describe a macrocycle that functions as ligand in
- 18 a complex.
- 19
- 20 13. The term "lanthanide macrocycle" means a complex where one or more lanthanide atoms
- 21 or ions are bound into the cavity of a macrocyclic ligand.
- 22 14. The abbreviation "LnMac" will be used to describe all of the functionalized macrocycles
- 23 taught in US Patents 5,373,093 and 5,696,240.
- 24
- 25 15. The registered trademark "Quantum Dye®" is and has been used to describe all of the
- 26 functionalized macrocycles taught in US Patents 5,373,093 and 5,696,240.
- 27 16. The term "unitary solution" is used to describe a homogenous solution that consists of a
- 28 single phase.
- 29 17. The term "unitary luminescence enhancing solution" is used to describe a unitary solution
- 30 that after evaporation of the solvent to dryness results in a solid that enhances the lumines-
- 31

1 cence of an energy transfer acceptor lanthanide(III) complex by a mechanism other than
2 completing the complexation of the lanthanide ion.

3
4 18. The term "homogeneous" is used to describe a material that has a constant composition
5 except for the material to be measured.

6 19. The term "homogeneous solid composition" is used to describe a material that does not
7 flow, contains two or more chemical species, and is homogenous.

8 20. The term "luminescence enhancing solid composition" is the homogeneous solid compo-
9 sition produced by the drying of the unitary luminescence enhancing solution.

10
11 21. The term "processed specimen" is used to describe the material present after conventional
12 clinical or research processing.

13 22. The term "labeled specimen containing composition" is used to describe a composition
14 that includes a processed specimen with one or more labels embedded in the luminescence
15 enhancing solid composition.

16
17 23. The terms "nucleic acid material" and "nucleic acids" each refer to deoxyribonucleotides,
18 ribonucleotides, or analogues thereof in either single- or double-stranded form. Unless
19 specifically limited, the term encompasses nucleic acids containing known analogues of
20 natural nucleotides that have similar properties as the reference natural or antisense
21 nucleic acid. Thus "nucleic acids" includes but is not limited to DNA, cDNA, RNA, anti-
22 sense RNA, double-stranded RNA, and oligonucleotides. A therapeutic nucleic acid can
23 comprise a nucleotide sequence encoding a therapeutic gene product, including a polypep-
24 tide or an oligonucleotide.

25 Nucleic acids can further comprise a gene (e.g., a therapeutic gene), or a genetic construct
26 (e.g., a gene therapy vector). The term "gene" refers broadly to any segment of DNA asso-
27 ciated with a biological function. A gene encompasses sequences including but not limited
28 to a coding sequence, a promoter region, a cis-regulatory sequence, a non-expressed DNA
29 segment that is a specific recognition sequence for regulatory proteins, a non-expressed
30 DNA segment that contributes to gene expression, a DNA segment designed to have
31 desired parameters, or combinations thereof. A gene can be obtained by a variety of meth-

ods, including cloning from a biological sample, synthesis based on known or predicted sequence information, and recombinant derivation of an existing sequence.

24. The term “energy transfer donor” is used to designate any molecular or ionic species capable of transferring all or part of the energy absorbed from light to another molecular or ionic species.

25. The term “energy transfer donor metal ion” is used to designate any metal ion that is itself, or is part of a complex that serves as, an “energy transfer donor”. This complex need not itself be ionic. This energy transfer can be direct or indirect if the presence of the metal ion induces another molecule or ion, including but not limited to those with which it has formed a complex, to transfer energy to another molecular or ionic species.

26. The term “energy transfer donor complex of a metal ion” is used to designate any complex of an energy transfer donor metal ion that is capable of transferring all or part of the energy absorbed from light to another molecular or ionic species.

27. The term “energy transfer acceptor” is used to designate any molecular or ionic species capable of accepting all or part of the energy absorbed from light by another molecular or ionic species.

28. The term “energy transfer acceptor lanthanide(III)” is used to designate a lanthanide(III) that accepts energy from one or more molecules or ions, and as a result of this process emits part of this energy as a photon.

29. The term “energy transfer acceptor lanthanide(III) complex” is used to designate any lanthanide(III) complex or compound that is capable of accepting energy, directly or indirectly, from an energy transfer donor and of emitting photons with energies equal to or less than the energy received.

30. The term “resonance energy transfer” is used to describe a process by which an energy transfer donor transfers energy to an energy transfer acceptor.

31. The term “RET” is an abbreviation for “resonance energy transfer”.

- 1 32. The term "heterogeneous resonance energy transfer" is used to describe a process by
2 which an energy transfer donor transfers all or part of the energy absorbed from light to an
3 energy transfer acceptor, where the energy transfer donor and energy transfer acceptor are
4 different molecular species.
- 5 33. The term "homogeneous resonance energy transfer" is used to describe a process by which
6 any molecular species transfers all or part of the energy absorbed from light to another
7 member of the same molecular species.
- 8
- 9 34. The term "columinescence" is used to describe the increase in luminescence brought
10 about by the addition of a luminescence-enhancing amount of at least one energy transfer
11 donor complex of a metal ion to one or more energy transfer acceptor lanthanide(III) com-
12 plexes, where the emission spectrum of the energy transfer donor species differs from that
13 of the one or more energy transfer acceptor lanthanide(III) complexes. The "term Lan-
14 thanide Enhanced Luminescence" that has been previously used is a synonym for columi-
15 nescence
- 16 35. The term "columinescence solution" is used to describe a solution, the use of which results
17 in "columinescence." The term "lanthanide enhanced luminescence solution" that has
18 been previously used is a synonym for columinescence
- 19 36. The term "LEL solution" is an abbreviation for "lanthanide enhanced luminescence solu-
20 tion."
- 21
- 22 37. The term "reactive functionality" is used to mean a first atom or group capable of reacting
23 with a second atom or group forming a covalent bond with it, as previously used in US
24 Patents 5,373,093 and 5,696,240 to mean that both the first and second atom or group are
25 capable of forming a covalent bond with one another. These atoms or groups include but
26 are not limited to amine, azide, alcoholic hydroxyl, phenolic hydroxyl, aldehyde, carboxy-
27 lic acid, carboxamide, halogen, isocyanate, isothiocyanate, mercapto and nitrile substitu-
28 ents. Functionalized alkyl, functionalized aryl-substituted alkyl, functionalized aryl, and
29 functionalized alkyl-substituted aryl signify the respective alkyl, aryl-substituted alkyl,
30 aryl, and alkyl-substituted aryl groups substituted with a reactive functionality.
- 31

- 1 38. A "peptide" is a polymer that is composed of monomer units that primarily are amino
2 acids. The peptide monomer units are linked to one another by amide bonds.
- 3
4 39. The term "label" means the species or moiety that permits a molecule to be detected or to
5 be affected non-destructively by a physical means.
- 6 40. The term "tag" is a synonym for "label".
- 7
8 41. The term "optical-label" means the species or moiety that permits a molecule to be
9 detected by optical means including emission of photons from both singlet and triplet
10 electronic excited states.
- 11 42. The term "labeled" designates a molecule that has formed a covalent bond with a label.
- 12
13 43. The term "tagged" is a synonym for "labeled".
- 14 44. The term "labeled-polymer" means a polymer to which one or more labels are attached.
- 15
16 45. The term "tagged-polymer" is a synonym for "labeled-polymer".
- 17 46. The term "labeled-polymer-conjugate" means a labeled-polymer where this polymer has
18 formed a covalent bond with a molecular species other than itself or its label(s).
- 19 47. The term "tagged-polymer-conjugate" is a synonym for is a synonym for "Labeled-poly-
20 mer-conjugate".
- 21
22 48. The term "fluorescence" means a process by which an electron of a molecule or ion that is
23 in an electronic singlet state (a state in which the spins of all electrons are paired) absorbs
24 the energy contained in one or more photons, with the result that this electron is elevated
25 to a higher energy singlet state, and subsequently an electron of this molecule or ion loses
26 energy in the form of a quantum of energy and deactivates to a lower energy state. This
27 process does not involve a change in the electronic spin multiplicity of the molecule or
28 ion. This quantum of energy can be in the form of an emission of a photon or transfer of
29 energy to a neighboring molecule or ion.
- 30 49. The term "fluorophore" means a molecule or ion capable of fluorescence.
- 31

- 1 50. The term "luminescence" means all processes by which an electron of a molecule or ion
2 absorbs the energy contained in one or more photons, with the result that this electron is
3 elevated to a higher energy singlet state, subsequently relaxes to a lower energy triplet
4 state, and subsequently energy is lost from an electron of this molecule or ion in the form
5 of a quantum of energy with the concurrent deactivation of this electron to a lower state.
6 This process involve a change of the electronic spin multiplicity of the molecule or ion.
7 This quantum of energy can be in the form of an emission of a photon or transfer of energy
8 to a neighboring molecule or ion.
- 9 51. The term "lumiphore" means a molecule or ion capable of luminescence.
- 10
11 52. The term "light absorption" means a process by which an electron in a molecule or ion
12 absorbs the energy contained in one or more photons.
- 13 53. The term "optical-label" means a label capable of fluorescence, luminescence, or absorp-
14 tion.
- 15
16 54. The term "luminescence-label" means an optical-label that is capable of luminescence,
17 such as a lanthanide macrocycle.
- 18 55. "The term fluorescence-label" means an optical-label that is capable of fluorescence.
- 19
20 56. "The term absorption-label" means an optical-label that is capable of absorption.
- 21 57. The term "specific combining pair" means a pair of molecules that forms a stable com-
22 plex.
- 23
24 58. The term "bridging molecule" means any molecule that can be simultaneously bound to a
25 label and a member of a specific combining pair.
- 26 59. The term "analyte" means any compound of interest, naturally occurring or synthetic, that
27 can bind to a member of a specific combining pair that is to be quantitated.
- 28
29 60. An "analyte-binding species" is the member of a specific combining pair that can form a
30 stable complex with an analyte. These analyte-binding species include but are not limited
31 to:

1 a) an antibody or antibody fragment.

2 (i) Such antibodies or fragments may be defined to include polyclonal antibodies
3 from any native source and native or recombinant monoclonal antibodies of classes
4 IgG, IgM, IgA, IgD, and IgE; hybrid derivatives, and fragments of antibodies includ-
5 ing Fab, Fab' and F(ab')₂; humanized or human antibodies; recombinant or synthetic
6 constructs containing the complementarity determining regions of an antibody, and the
7 like. The methods useful for construction of all such antibodies are known to those of
8 skill in the art.

9
10 b) a polynucleotide, polynucleotide fragment, or an oligonucleotide.

11 (i) Such polynucleotides, polynucleotide fragments, or oligonucleotides include
12 but are not limited to: deoxynucleic acids, DNAs; ribonucleic acids, RNAs; and pep-
13 tide nucleic acids, PNAs.

14
15 c) a protein that is a member of specific combining pair.

16 (i) Such proteins include but are not limited to avidin, streptavidin, and their
17 derivatives.

18
19 d) a lectin.

20 61. The term "indirectly labeled" means a process where an analyte-binding species is a mem-
21 ber of two specific combining pairs. The other member of the first specific combining pair
22 is a labeled molecule. The other member of the second specific combining pair is an ana-
23 lyte. The analyte-binding species is bound to both the analyte and the labeled molecule.

24 62. The term "co-hybridization" means a process where two DNA samples differing in at least
25 one property are hybridized with a third DNA.

26
27 63. The term "material" is defined to include: cells, organisms, bacteria, viruses, histological
28 sections, organic and inorganic particulates and matter, and any other discernible material
29 which provides diagnostic and/or analytical information whatsoever.

30

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1 64. The term "microscopic analysis" is defined to be a process wherein a microscope under
2 human and/or a machine control is used for visualization, analysis, and/or enumeration,
3 and/or categorization, and/or photography, and/or electronic image acquisition of material.

4 65. The term "receiving surface member" will be used in a generic sense to describe all dis-
5 crete objects which serve as substrates to support material for microscopic viewing and/or
6 observation and/or analysis. The current, most common receiving surface member is a
7 microscope slide, which is a glass rectangular object that is approximately 1 mm thick, 25
8 mm wide, and 75 mm long. These are the items conventionally referred to as microscope
9 slides for laboratory and commercial purposes.

10
11 As used herein and in the appended statements of the invention, the singular forms "a",
12 "and", and "the" include plural referents unless the context clearly dictates otherwise. Thus,
13 for example, reference to "a construct" includes a plurality of such constructs, and so forth.

14 The term "about", as used herein when referring to a measurable value such as an amount
15 of weight, time, dose, etc. is meant to encompass variations of in one embodiment $\pm 20\%$ or \pm
16 10% , in another embodiment $\pm 5\%$, in another embodiment $\pm 1\%$, and in still another embod-
17 iment $\pm 0.1\%$ from the specified amount, as such variations are appropriate to perform the dis-
18 closed methods.

19 The term "expression", as used herein to describe a genetic construct, generally refers to
20 the cellular processes by which a biologically active polypeptide or biologically active oligo-
21 nucleotide is produced from a DNA sequence.

22 The term "construct", as used herein to describe a genetic construct, refers to a composition
23 comprising a vector used for gene therapy or other application. In one embodiment, the com-
24 position also includes nucleic acids comprising a nucleotide sequence encoding a therapeutic
25 gene product, for example a therapeutic polypeptide or a therapeutic oligonucleotide. In one
26 embodiment, the nucleotide sequence is operatively inserted with the vector, such that the
27 nucleotide sequence encoding the therapeutic gene product is expressed. The term "construct"
28 also encompasses a gene therapy vector in the absence of a nucleotide sequence encoding a
29 therapeutic polypeptide or a therapeutic oligonucleotide, referred to herein as an "empty con-
30 struct." The term "construct" further encompasses any nucleic acid that is intended for in vivo
31 studies, such as nucleic acids used for triplex and antisense pharmacokinetic studies.

The terms “bind”, “binding”, “binding activity” and “binding affinity” are believed to have well-understood meanings in the art. To facilitate explanation of the present invention, the terms “bind” and “binding” are meant to refer to protein-protein interactions that are recognized to play a role in many biological processes, such as the binding between an antibody and an antigen, and between complementary strands of nucleic acids (e.g. DNA-DNA, DNA-RNA, and RNA-RNA). Exemplary protein-protein interactions include, but are not limited to, covalent interactions between side chains, such as disulfide bridges between cysteine residues; hydrophobic interactions between side chains; and hydrogen bonding between side chains.

The terms “binding activity” and “binding affinity” are also meant to refer to the tendency of one protein or polypeptide to bind or not to bind to another protein or polypeptide. The energetics of protein-protein interactions are significant in “binding activity” and “binding affinity” because they define the necessary concentrations of interacting partners, the rates at which these partners are capable of associating, and the relative concentrations of bound and free proteins in a solution. The binding of a ligand to a target molecule can be considered specific if the binding affinity is about $1 \times 10^4 \text{ M}^{-1}$ to about $1 \times 10^6 \text{ M}^{-1}$ or greater.

The phrase “specifically (or selectively) binds”, for example when referring to the binding capacity of an antibody, also refers to a binding reaction which is determinative of the presence of the antigen in a heterogeneous population of proteins and other biological materials. The phrase “specifically (or selectively) binds” also refers to selective targeting of a targeting molecule, such as the hybridization of a RNA molecule to a nucleic acid of interest under a set of hybridization conditions as disclosed herein below.

Table of Abbreviations

BSA	bovine serum albumin
cDNA	complementary DNA
CIA	chloroform/isoamyl alcohol
CTAB	cetyltrimethylammonium bromide
dATP	deoxyadenosine triphosphate
dCTP	deoxycytidine triphosphate

dGTP	deoxyguanosine triphosphate
DMF	dimethylformamide
DMSO	dimethylsulfoxide
DNA	deoxyribonucleic acid
dNTP	deoxynucleotide triphosphate
dTTP	deoxythymidine triphosphate
dUTP	2'-deoxyuridine 5'-Triphosphate
EDTA	ethylenediaminetetraacetic acid
E _{qv}	equivalent(s)
E _{qv} /L	equivalent(s) per Liter
EuMac-d-UTP	EuMac-5-deoxyuridine triphosphate
h or hr	hour(s)
H ₂ PDCA	2,6-pyridinedicarboxylic acid
HTTFA	thenoyltrifluoroacetone
L	liter(s)
LEL	Lanthanide Enhanced Luminescence
Ln(III) or Ln ³⁺	a trivalent lanthanide cation
LnMac	See Definition 14.
LnMac-d-UTP	LnMac-5-deoxyuridine triphosphate
M	molar
M	molar
mg	milligram(s)
min	minute(s)
mL	milliliter(s)
mM	millimolar
mm	millimeter
mmol	millimole(s)

mmol/L	millimoles per liter
mRNA	messenger RNA
msec	millisecond(s)
nEqv	nanoequivalent
ng	nanogram(s)
nmol	nanomole(s)
PB	phosphate buffer
PBS	phosphate buffered saline
PCR	polymerase chain reaction
PDCA	The dianion of 2,6-pyridinedicarboxylic acid
PEG	polyethylene glycol
RET	Resonance Energy Transfer
RNA	ribonucleic acid
rpm	revolutions per minute
SDS	sodium dodecyl sulfate
sec	seconds(s)
SmMac-d-UTP	SmMac-5-deoxyuridine triphosphate
TbMac-d-UTP	TbMac-5-deoxyuridine triphosphate
TTFA	The anion of thenoyltrifluoroacetone
μg	microgram(s)
μL	microliter(s)
μM	micromolar
μmol	micromole(s)
μmol/L	micromoles per liter
μsec	microsecond(s)

FIELD OF THE INVENTION

1 This invention concerns: Composition of matter and a process to enhance and/or modify
2 the luminescence of covalently coupled optical-labels containing lanthanide(III) complexes,
3 especially when functioning as labels for detecting members of combining pairs, and to permit
4 the detection and quantitation of low levels of these optical-labels.

5 To facilitate the use of references in this text, the citations are given in full at the end. The
6 reference number preceded by Ref. in parenthesis (Ref. number) is employed for citations.

7 Citations to books include the first page or chapter of the section of interest. US patents are
8 cited both by number and as references.

9

1. Prior Art

10 Vallarino and Leif have reported in US Patent 5,373,093, 1994 (Ref. 1) and its Continua-
11 tion-In-Part US Patent 5,696,240, 1997 (Ref. 2) on symmetrically di-functionalized water sol-
12 uble macrocyclic complexes of lanthanide, actinide, and yttrium ions. A di-functionalized
13 macrocyclic complex is represented by the schematic Formula I:

14

15

16

17

18

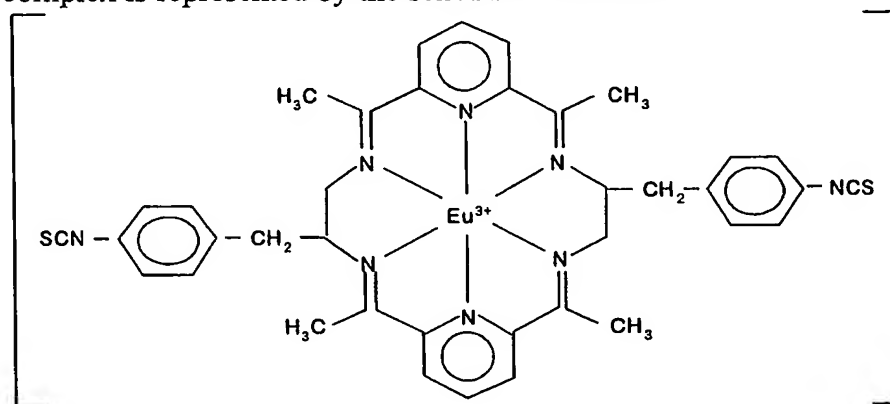
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22

Formula I



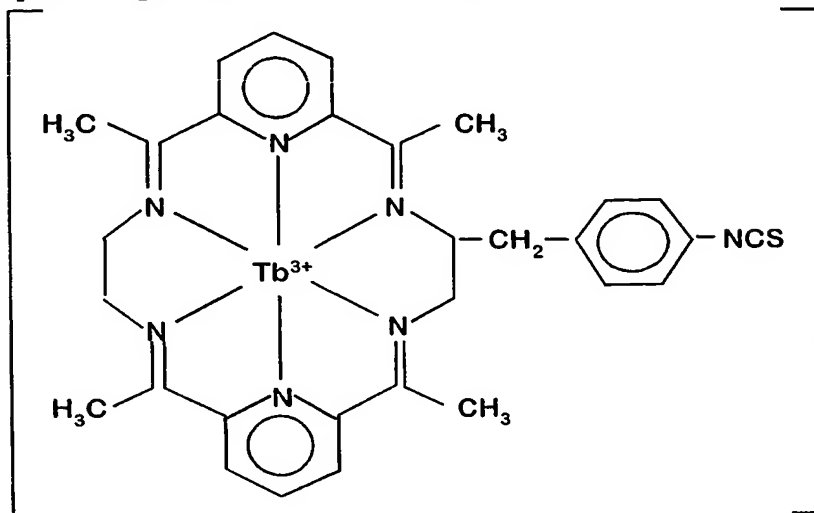
23 Formula I is the di-isothiocyanate derivative having the structure shown in column 10 of
24 US Patent 5,373,093. Specifically, it is one of the isomers of the cationic europium macrocy-
25 clic moiety containing a 4-isothiocyanato-benzyl- substituent on each of the aliphatic side-
26 chains. The empirical formula of the moiety is $\text{C}_{38}\text{H}_{36}\text{N}_8\text{S}_2\text{Eu}$. Its trichloride was used in liq-
27 uid phase coupling reactions of this application. The organic macrocycle and its functional-
28 ized derivatives act as ligands to lanthanide, actinide and yttrium ions.

29

30

31

1 In US Patent 5,696,240, asymmetrically mono-functionalized water soluble macrocyclic
 2 complexes of lanthanide, actinide and yttrium ions are described. A mono-functionalized
 3 macrocyclic complex is represented by the schematic Formula II:



13 Formula II

14
 15 Formula II is the mono-isothiocyanate derivative having the structure shown in Claim 13
 16 of US Patent 5,696,240. Specifically, it is the cationic terbium macrocyclic moiety containing
 17 a 4-isothiocyanto-benzyl-substituent on one of the aliphatic side-chains. The empirical for-
 18 mula of the moiety is C₃₀H₃₁N₇STb.

19 The following abbreviations will be used to describe species having structures related to
 20 those shown in Formula I, Formula II, and subsequent Formulas.

21 Any and all of the metal ions selected from the group consisting of a lanthanide having
 22 atomic number 57-71, an actinide having atomic number 89-103, and yttrium having atomic
 23 number 39 will have M as their abbreviation in formulas. Specific metal ions will be given as
 24 their standard chemical symbols. The unfunctionalized, mono-functionalized and di-function-
 25 alized macrocyclic complexes will be abbreviated respectively as "Mac-un", "Mac-mono"
 26 and "Mac-di". The term "Macs" without the -un, -mono, or -di suffix will include the unfunc-
 27 tionalized, mono-functionalized and di-functionalized macrocyclic complexes (Mac-un, Mac-
 28 mono and Mac-di). When a specific peripheral pendant substituent having at least one reactive
 29 site (reactive functionality) is mentioned, its abbreviation will be given as a suffix. Thus, the
 30 compound shown in Formula I is abbreviated as EuMac-di-NCS. The compound shown in
 31 Formula II is abbreviated as TbMac-mono-NCS. The abbreviation, LnMac, will refer to any

1 and all of the macrocyclic species covered by US patents 5,373,093 and 5,696,240. These
2 macrocyclic species are lanthanide(III) complexes. These can be referred to as compounds. In
3 the solid state, in order to achieve electronic neutrality, they have accompanying anions, such
4 as chlorides.

5 The entire disclosures of US Patent 5,373,093 and its Continuation-In-Part US Patent
6 5,696,240 are here incorporated by reference.

7 Leif et al. 1994 (Ref. 3) described the use of symmetrically di-isothiocyanate-functional-
8 ized macrocyclic complexes of a lanthanide(III) ion, which served as the light-emitting center.
9 The isothiocyanate functionalities allow covalent coupling of the lanthanide(III) macrocycles
10 to a biosubstrate. The Eu(III) and Tb(III) macrocyclic complexes possess a set of properties --
11 water solubility, inertness to metal release over a wide pH range, ligand-sensitized narrow-
12 band luminescence, large Stoke's shift, and long excited-state lifetime -- that provide ease of
13 staining as well as maximum emission signal with minimum interference from background
14 autofluorescence. These authors stated, "The results with the $^5D_0 \rightarrow ^7F_2$ (610-625 nm)
15 Eu(III) transition, which is the major signal source, show that the luminescence of the EuMac-
16 enhancer system is highly dependent upon the choice of both buffer and solvent. The emission
17 intensity increases dramatically in the absence of those buffers that contain anions, such as
18 carbonate, capable of competing with the β -diketonate enhancers as ligands for Eu(III). The
19 emission intensity also increases greatly in the less hydroxylic solvents. However, vibrational
20 deactivation by interaction with the -OH groups of solvent molecules can not be solely
21 responsible for the energy loss, since substitution of D₂O for H₂O as the solvent had been
22 reported (Ref. 4) to result only in a three-fold increase of the EuMac excited-state lifetime."

23 The low quantum yield of the emission of the EuMac in aqueous medium probably pre-
24 cludes its use as an optical-label for the observation and measurements of live cells (Ref. 3).
25 However, this complex can be used in conventional fluorescence (luminescence) microscopy,
26 providing the cells are mounted in the appropriate nonaqueous medium.

27 Leif and Vallarino have taught in US Patents 6,340,744 (Ref. 5) and 6,750,005 (Ref. 6) "A
28 spectrofluorimetrically detectable luminescent composition comprising water, a micelle-pro-
29 ducing amount of at least one surfactant, at least 1×10^{-10} moles/liter of at least one energy
30 transfer acceptor lanthanide element macrocycle compound having an emission spectrum
31

1 peak in the range from 500 to 950 nanometers, and a luminescence-enhancing amount of at
2 least one energy transfer donor compound of yttrium or a 3-valent lanthanide element having
3 atomic number 59-71, provided that the lanthanide element of said macrocycle compound and
4 the lanthanide element of said energy transfer donor compound are not identical.”

5 The enhanced luminescence of compositions according to US Patents 6,340,744 and
6 6,750,005 permits the detection and/or quantitation of the lanthanide(III) macrocycle com-
7 pounds and complexes thereof without the use of expensive and complicated time-gated
8 detection systems. As a result, these macrocycle compounds and complexes thereof are useful
9 as reporter molecules in immunoassays, analytical cytology, histological staining, and imag-
10 ing processing.

11 The increase in emission intensity of the lanthanide enhanced luminescence solutions
12 according to US Patents 6,340,744 and 6,750,005, caused by an energy transfer donor com-
13 plex of a different metal ion, can also occur with functionalized derivatives of energy transfer
14 acceptor lanthanide(III) complexes, for instance with lanthanide macrocycles containing one
15 or more reactive functional groups at which reaction with analyte-binding species and/or ana-
16 lytes can take place; with reaction products of functionalized derivatives of such energy trans-
17 fer acceptor lanthanide(III) complexes with such analyte-binding species and/or analytes. The
18 analytes include small molecules of biological interest having molecular weights from 125 to
19 2000 daltons, such as nucleic acid bases or haptens, and large molecules of biological interest
20 having molecular weights greater than 2000 daltons, such as proteins including antibodies,
21 polysaccharides, or nucleic acids.

22 In a preferred composition according to US Patent 6,340,744, the energy transfer donor
23 compound is an ionic compound of, or a complex of, gadolinium(III). The gadolinium(III)
24 halides and especially gadolinium(III) trichloride are particularly preferred.

25 The enhanced luminescence composition of US Patent 6,340,744 exists in a micellar orga-
26 nization. The importance of micellar organization to the enhanced luminescence composition
27 is demonstrated by the observation that a water-miscible polar solvent such as ethanol, when
28 added to the characteristically cloudy and luminous composition, completely eliminates the
29 luminescence and simultaneously turns the cloudy micellar liquid to a clear solution. Once
30 formed in an aqueous micellar organization, the composition of US Patent 6,340,744 can be
31

1 transferred to an immiscible non-aqueous medium and/or dried, as by evaporation or lyo-
2 philization, with preservation of its luminescence. To provide the micellar organization, the
3 composition includes a micelle-forming amount of a surfactant.

4 Cetyltrimethylammonium bromide, a cationic surfactant, is used in the preferred embodi-
5 ment of US Patent 6,340,744. The preferred concentrations for this surfactant range from
6 1.0×10^{-4} to 1.0×10^{-6} M.

7 The entire disclosure of US Patents 6,340,744 and 6,750,005 are here incorporated by ref-
8 erence.
9

10 **Columinescence (LEL)**

11 Xu and Hemmila (Ref. 7) have described a luminescence enhancement system consisting
12 of the ternary chelates of the lanthanide ions Eu^{3+} , Sm^{3+} , Tb^{3+} or Dy^{3+} with PTA (Pivaloyltri-
13 fluoroacetone) and 1,10-phenanthroline (Phen) using Y^{3+} as the enhancing ion. Ref 7 states,
14 "The optimum PTA concentration for Tb^{3+} detection was narrow and the fluorescence dimin-
15 ished rapidly at PTA concentrations above 70 μM , whereas for Eu^{3+} detection the optimum
16 PTA concentration was wider (Fig 1), 50 μM PTA was used in subsequent experiments." The
17 optimum concentration of 1,10-phenanthroline was 50 μM . Triton X-100 was employed as the
18 surfactant. The greatest luminescence enhancement was produced by Y(III) at 75 μM , which
19 was followed by Lu(III) and Gd(III). The enhancement with these two ions was essentially
20 equal; and greater than the enhancement with La(III). The pH optimum of the columinescence
21 solution was between 7.2 and 7.3. Increases in the ethanol concentration "decreased the Eu^{3+}
22 fluorescence but did not change the Tb^{3+} fluorescence at Triton X-100 concentrations below
23 its critical micelle concentration (0.015%)." As shown in Fig. 3 of Ref 7, The luminescence of
24 both Eu(III) and Tb(III) decreased independently of the Triton X-100 concentration when the
25 ethanol concentration was above 30%. The complexes of the Eu(III), Tb(III), Sm(III), and
26 Dy(III) had excitation maxima in the range of 312 to 316 nm and emission maxima respec-
27 tively at 612, 544, 647, and 574 nm. The lifetimes of the Eu(III) and Tb(III) complexes were
28 longer and the detection limits greater than those of the Sm(III), and Dy(III).

29 Tong et al. (Ref. 8) have described the enhancement of the luminescence of the complex of
30 Dy(III) with 1,6-bis(1'-phenyl-3'-methyl-5'-pyrazol-4'-one)hexanediol (BPMPhD) by the
31 cationic surfactant cetyltrimethylammonium bromide (CTMAB) [CTAB] and Gd(III). The

1 excitation and emission maxima were respectively 300 nm and 578 nm. The fluorescence
2 intensity of the Dy–BPMPHD system was reported to be enhanced about sevenfold by adding
3 CMTAB with a further eightfold enhancement by the addition of Gd(III). The necessity of a
4 miscellular system for the columinescence effect was demonstrated by Tong et al., who stated,
5 “that the fluorescence intensity of the system changes greatest when CTMAB is at its apparent
6 cmc (critical miscellular concentration) indicates that the formation of micelles has a great
7 effect on the increase in the fluorescence intensity in the system.” A miscellular system was
8 also demonstrated (Ref. 8) to be required for maximum luminescence because “The co-lumi-
9 nescence effect disappeared if the organic solvent concentrations were more than 70% for eth-
10 anol, 50% for acetone and 80% for dimethyl sulfoxide, when the turbid system became
11 transparent.” Tong et al. concluded, “From the effects of surfactants and solvents on the fluo-
12 rescence intensity, we conclude that the co-luminescence effect only occurs in the surfactant
13 micellar system or turbid coprecipitated system.” This confirms the intermolecular energy
14 transfer luminescence mechanism.

15 Tong et al. (Ref. 8) described the mechanism of columinescence as being, “Because Gd^{3+}
16 possesses a relatively stable half-filled 4f shell and the luminescence level of $Gd^{3+} \ ^6P_{7/2}$ is
17 higher than the triplet state of BPMPHD in the complex $[Gd(BPMPHD)_2] \cdot CTMAB^+$, the
18 energy of the latter cannot be transferred to Gd^{3+} , but can be transferred to the luminescence
19 $^4F_{9/2}$ level of Dy^{3+} in the $[Dy(BPMPHD)_2] \cdot CTMAB^+$ complex by intermolecular energy
20 transfer owing to the short distance between the two complexes in the micelle.” This same
21 explanation can also be applied to the effect of Gd(III) on the EuMac, TbMac, and SmMac in
22 a miscellular solution.

23 Yang et al. (Ref. 9) described luminescence studies of doped silica gels and coprecipitates
24 in the form of powders of complexes of TTFA and phenanthroline with either 100% Eu(III) or
25 80% Eu(III) and 20% Gd(III). In the case of the powdered complexes, the presence of the
26 Gd(III) increased the luminescence produced by the Eu(III) in the coprecipitates by about
27 47% and decreased the luminescence produced by the Eu(III) in the doped silica gels by about
28 18%. The effect of distance on energy transfer was proposed to explain these opposite effects.
29 It was proposed that the Gd(III) complexes were nearer to the Eu(III) powdered complexes in
30 the coprecipitates than in the doped silica gels.

1 Blasse et al. (Ref. 10) described emission of a Tb(III) impurity of $\text{La}(\text{2,2'}\text{-bipyridine})_3^{3+}$.
2 The material was prepared for luminescence spectroscopy by being "pressed in the cryostat on
3 a bed of MgO." They reported that, "Upon measuring the emission spectrum as a function of
4 temperature, a peculiar phenomenon occurred. A certain amount of Tb^{3+} emission appeared
5 when the ligand phosphorescence intensity decreased." As shown in Figure 2 of Ref. 10, the
6 Tb(III) emission rapidly increased when the temperature was raised from 4.2 K to about 100
7 K and then rapidly decreased to about background at 200 K. Blasse et al. stated, "This behav-
8 ior of the Tb^{3+} impurity emission, suggest strongly that the $^3(\pi, \pi^*)$ excited state is not local-
9 ized but migrates among the several bpy (2,2'-bipyridine) groups." This migration includes
10 the transfer of energy to the Tb(III).

11 The term LEL is used; rather than cofluorescence because LEL was used in the patents and
12 publications described below. The limited stability and reproducibility of the micellar Lan-
13 thanide Enhanced Luminescence solution described by Leif and Vallarino in US Patents
14 6,340,744 (Ref. 5) and 6,750,005 (Ref. 6), by Bromm et al. 1999 (Ref. 11) and Quagliano et
15 al. 2000 (Ref. 12), as well as the impairment of cellular morphology by the emulsifying agents
16 are significant problems that have impeded commercialization. In order to have a reliable,
17 convenient commercial product, the LEL emulsion needs to be stored and shipped, preferably
18 in the form of a single material. However, this option has intrinsic difficulties, because the
19 LEL emulsion is both temperature and oxygen sensitive; it also deteriorates upon prolonged
20 storage at 4°C. At present, the LEL emulsion is prepared at the time of use by the addition of a
21 small amount of an ethanolic solution to an aqueous solution, followed by rapid mixing. The
22 LEL aqueous component contains GdCl_3 , salts, buffer, detergent and gelatin. The water used
23 for the buffer is boiled to remove oxygen prior to the addition of the ingredients. The LEL eth-
24 anolic solution contains: HTTFA, cetyltrimethylammonium bromide, and 1,10-phenanthro-
25 line. The extent of luminescence enhancement produced by this solution depends on the
26 method of mixing, the time elapsed after mixing, and the oxygen content of the solution. The
27 micellar solution is also sensitive to temperatures above 60 °C.

28 Ultrasonication was explored because it had the potential of increasing the reproducibility
29 of the luminescence enhancement by reproducibly forming a solution containing small
30 micelles with minimal size dispersion, which should enhance the shelf-life of a one-compo-
31 nent Luminescence solution. A Branson Model 450 Digital Sonifier with a High-intensity

1 Cup Horn was extensively tested. The use of the water cooled Cup Horn had the significant
2 potential advantage of permitting the LEL solution to be emulsified in a standard plastic
3 screw-top 50 mL vial. This eliminated the problems of metal contamination from the standard
4 ½" Horn container and of aerosol production. Unfortunately, the homogenization was often
5 incomplete and the luminescence was decreased.

6 In order to create a closed, effectively cooled system, the original High-intensity Cup Horn
7 was replaced by a flow-through ultrasonic horn. The liquid was cooled prior to its entry into
8 the head and after it exits. However, this did not solve the problem of the decrease in lumines-
9 cence resulting from ultrasonic mixing. It was concluded that the loss of intensity of the LEL
10 solution stored as a single material was too high to be acceptable.

11 It was found that the addition of antioxidants and fluorescence protecting agents also
12 caused a decrease in luminescence.

13 These experimental observation pointed out the shortcomings of a single material LEL
14 solution. Therefore, the product is to be supplied as one aqueous and one ethanolic solution to
15 be mixed at the time of use. It was also observed that the originally developed LEL solution
16 impaired cellular morphology and did not produce significant luminescence when EuMac-
17 streptavidin was bound to biotinylated microtiter plates. This loss of luminescence was pre-
18 sumably caused by the desorption of the biotin from the plastic microtiter plates. These prob-
19 lems were solved by replacing the trioctylphosphine oxide (TOPO) by gelatin in the LEL
20 solution (Ref. 13).

21 The photo-decomposition of some component of the LEL solution (presumably, the
22 HTTFA) resulted in a loss of luminescence. This loss could be reversed by the addition of new
23 LEL solution, and it was noted that the rate of luminescence loss was much slower for a plas-
24 tic embedded sample than for the aqueous LEL solution (Ref. 13).

25 Some of the content of the provisional application (serial number 60518605) for this inven-
26 tion has been published (Ref. 14).

27 **Europium Macrocycle Labeled Peptides**

28 The solid phase synthesis of peptides labeled with the europium macrocycle, and capable
29 of subsequent coupling with biologically active and/or biologically compatible molecules, has
30 been described (Refs. 15 & 16). These europium macrocycle-labeled peptides have been spe-
31

1 cifically cleaved by an enzyme, Proteinase K, from a solid phase support. After washing and
2 in the presence of the enhanced luminescence composition of US Patent 6,340,744, both the
3 intact bead-bound peptide and the beads after enzymatic cleavage showed typical europium
4 luminescence under UV excitation. However, the luminescence from the intact beads was
5 strong and the luminescence from the beads after cleavage was weak. This strong lumines-
6 cence demonstrated that significant amount of europium macrocycle had coupled to the pep-
7 tide. The drastic difference in luminescence before and after Proteinase K hydrolysis
8 demonstrated that the europium macrocycle-labeled part of the peptide had been released
9 from the beads by hydrolysis.

10 Two Photon (Up-Conversion) Excitation Of Lanthanide Luminescence

11
12 Solutions of neodymium ion, Nd(III), complexes have been recently reported (Xiao et al.
13 Ref. 17.) to upconvert, emitting at wavelengths shorter than those employed for excitation.
14 Since "For one color excitation the emitted light depends quadratically on the incident laser
15 power", and the excitation wavelength was longer (590 nm) than the strongly emitted wave-
16 lengths, "located near 360 nm, 387 nm, and 417 nm" this evidently was two photon excitation.
17 More efficient upconversion was observed with ethylenediaminetetraacetic acid (EDTA) than
18 with dipicolinic acid (DPA), otherwise known as 2,6-pyridinedicarboxylic acid (H₂PDCA).
19 These authors also studied the use of excitation by two lasers, one of which emitted between
20 592 and 599 nm and the other between 791 and 799 nm. The lifetime of the first excited state
21 (⁴F_{3/2}), produced by excitation near 800 nm, was much longer (55 to 684 ns) than the lifetime
22 (less than 20 ns) of the emitting excited state (⁴D_{3/2}) produced by excitation near 590 nm. The
23 substitution of D₂O for H₂O reduced "the nonradiative transfer of the excited state energy of
24 the rare earth ion to the high frequency O-H bond vibrations that exist in the H₂O solution
25 resulting in longer decay lifetimes and more efficiency."

26 In US Patent 5,698,397 (Zarling et al., Ref. 18), the definition of the label stated (Col. 10),
27 "The label can alternatively comprise a lanthanide ion in a chelate or cage compound." In
28 Table I (Col. 16), "various phosphor material compositions capable of up-conversion" are
29 listed. They consist of a host material, an absorber ion, an emitter ion and the visible color of
30 the emission.

1 In the section of US Patent 5,698,397, Evaluation of Up-converting Chelates (Col. 54), the
2 patent teaches only the successful up-conversion of complexes that contain one species of lan-
3 thanide ion. They studied separately complexes of the single lanthanide ions, erbium(III) and
4 neodymium(III), which "have been prepared with ethylenediaminetetraacetic acid (EDTA)
5 and dipicolinic acid (DPA)." The patent states, "The erbium chelates were pumped using light
6 near 793.5 nm from a Ti:sapphire laser (the excitation scheme of Macfarlane (1989) Appl.
7 Phys. Lett 54: 2301). This approach produced upconversion but not satisfactorily, which we
8 attribute to weak absorption for the first step due to the increase in linewidth in the chelate
9 over the low temperature crystal used for the up-conversion laser." However, the 380 nm
10 emission of the neodymium chelates, when they were excited in the visible at 580 nm, was
11 obtained.

12 This patent teaches (Col. 30), "Energy transfer can be efficient in a crystalline host contain-
13 ing many rare earth ions, but not in a solution where the concentration of ions is low and the
14 phonon structure is less constrained."

15 Another patent (Kardos et al., US 6,159,686, Ref. 19) based on the same parent application
16 states, "Rare earth chelates may be used as up-converting reporters through stepwise excita-
17 tion such as shown in FIG. 5a, or in FIG. 5b (except that all levels would be in the same ion).
18 Energy transfer from a sensitizer ion to an activator ion cannot be used in the case of a single
19 rare earth ion." This statement is clearly contradicted by the content of the present patent.

20 Zarling et al. (US 6,399,397, Ref. 18) have described the instrumentation necessary for up-
21 conversion, two photon excitation of phosphor particles. In their Experimental Examples, as
22 demonstrated in their figures 11 and 12, they observed up-conversion at a very low power
23 density of 1,000 W/cm². Specifically, submicron particles Na(Y_{0.80}Yb_{0.18}Er_{0.02})F₄ that had
24 been coated with polycarboxylic acid, when excited at approximately 977 nm, emitted at 541
25 nm. These Authors stated that the "maximal phosphorescence appears at approximately 400
26 μsec. with a gradual decay to a lower, stable level of phosphorescence at about 1000 μsec."

27 Ligands

28 Two new types of luminescent lanthanide complexes have been synthesized recently by
29 Raymond's group. The first type includes complexes (Ref. 20) of hydroxyisophthalamidyla-
30 mide-based bidentate, tetradentate and higher polydentate ligands, containing a single lan-
31

1 thanide ion. Excitation between 350 to 360 nm produced strong emission from the europium
2 and terbium complexes of the H22IAM ligand, which is the unfunctionalized tetradentate
3 ligand. The second type of complexes (Ref. 21) was similarly based on ligands containing the
4 salicylamidyl moiety. The US Patent 6,406,297 (Ref. 21) states that there was "one type of
5 complex in solution"; and "the stability of this complex is low." The spectra were reported as
6 taken in a nonaqueous solvent, acetonitrile.

7 Murthy and Suva (Ref. 22), herein incorporated by reference, have described ligands for
8 europium and other lanthanide ions that form complexes with excitation maxima at wave-
9 lengths longer than 360 nm. These compounds included a β -diketone terminated at end with
10 "a substituted aromatic, heterocyclic aromatic or substituted heterocyclic aromatic group;"
11 and a second group "independently selected from monocyclic aryl groups, multi-cyclic aryl
12 groups". More complex structures included a third group "selected from monocyclic aryl
13 groups, multi-cyclic aryl groups". The peak excitation wavelengths of the europium ion com-
14 plexes of their PNPD and NNPD compounds were 390 nm and 400 nm, respectively. US
15 Patent Application 20040082768 (Ref. 22) also teaches that "it is possible to avoid hydration
16 (of their complexes) with water molecules where one of the Aryl moieties is further substi-
17 tuted adjacent to the diketone substituent with an additional chelating moiety." In Fig. 4 of this
18 patent, this moiety is shown as a methyl ester.

19 Jones, II, et al. US 6,402,986 (Ref. 23), herein incorporated by reference, teaches chemical
20 structures of ligands that form luminescent chelates with lanthanide ions, specifically
21 europium and terbium ions. Four of these ligands were derived from 2, 6-pyridinedicarboxy-
22 late and two were based upon terpyridinedicarboxylate. The proposed use of these chelates
23 was to serve as taggants that when applied to multiple materials would provide "a multi-
24 parameter signature for purposes of comparative light decay analysis of verification marks or
25 features." The resistance to photodegradation of these Eu(III) ligands by "intermittent sunlight
26 filtered by common exterior glass light" was much higher than that of "europium complexes
27 of the diketonate class encompassing, for example, the ligands, naphthoyltrifluoroacetate
28 and benzoyltrifluoroacetate". The lifetimes of the Eu(III) and Tb(III) chelates of ligands 1
29 to 5 of US 6,402,986 were all increased by imidazole and 4-methylimidazole, and iminodiace-
30 tic acid decreased the lifetimes of ligands 1 to 4. US 6,402,986 describes the benefits of the
31 use of poly(vinyl acetate) (PVA) with a molecular weight in the range of 10,000-500,000 KD:

1 “Increases of 30-40 fold in luminescence intensity and lifetime are observed for ink composi-
2 tions that include moderate concentrations of PVA (mM range).”

3 Lehn and coworkers have created functionalized cryptates which are macropolycyclic rare
4 earth complexes (Refs 24,25,26) which have the advantages of a high quantum yield of fluo-
5 rescence and a high molar absorption coefficient, stability, solubility in, and non-inhibition by
6 water or other solvent or by molecules present in the medium in which the measurement.
7 Cryptates are selectively chelated by lanthanides in solutions containing other cations.

8 Lehn and coworkers have created lanthanide(III) cryptates in which the lanthanide(III) ions
9 are complexes within the three-dimensional cavity of functionalized macropolycyclic ligands
10 termed cryptands (Refs 24,25,26) herein incorporated by reference. These lanthanide(III)
11 cryptates have the advantages of a high quantum yield of luminescence, a high molar absorp-
12 tion coefficient, stability, solubility in water and other solvents, and resistance to decomposi-
13 tion or luminescence inhibition by water, other solvents, or molecules present in the medium
14 in which the measurement is performed. The lanthanide ions are selectively complexed by
15 cryptands in solutions containing other metal ions.

16 **Other Lanthanide Ions**

17 Hofstraat, US Application 20020187563 (Ref. 27) herein incorporated by reference,
18 teaches ion-ligand complexes of the neodymium(III) ion, Nd(III), ytterbium(III) ion, Yb(III),
19 or erbium(III) ion, Er(III), with derivatives of polyaminocarboxylic acids and pyridinedicar-
20 boxylic acid. These derivatives include sensitizing moieties derived from conventional
21 organic fluorophores that absorb in the region of 400-1,000 nm. Excitation at 500 nm resulted
22 in emissions from fluorexon complexes of Nd(III) (880, 1060, 1320 nm), Yb(III) (980 nm),
23 and Er(III) (1530 nm). Both water and deuterium oxide were studied as solvents. The life-
24 times of the DPTA-fluorescein and DPTA-eosin complexes of these lanthanide ions ranged
25 from 1 to 0.5 μ sec in D₂O and from 0.61 to 0.15 μ sec in H₂O. These lifetimes are “about two
26 orders of magnitude shorter than that of the prior art Eu(III) and Tb(III) complexes.”

27 SUMMARY OF THE INVENTION

28
29 In accordance with the invention, there is provided a unitary luminescence enhancing solu-
30 tion that contains a solvent, an energy transfer donor and after drying in the presence of an
31 energy transfer acceptor lanthanide ion complex results in a solid that enhances the lumines-

1 cence of the energy transfer acceptor lanthanide ion complex by a mechanism other than com-
2 pleting the complexation of the lanthanide ion.

3 The energy transfer donor is at least one substance selected from the group consisting of a
4 fluorophore, a lumiphore, or combination thereof. A fluorophore is a molecule or ion or com-
5 plex capable of fluorescence, i.e. any process by which an electron of a molecule or ion that is
6 in an electronic singlet state (a state in which the spins of all electrons are paired) absorbs the
7 energy contained in one or more photons, with the result that this electron is elevated to a
8 higher energy singlet state, and subsequently an electron of this molecule or ion loses energy
9 in the form of a quantum of energy and deactivates to a lower energy state. This process does
10 not involve a change in the electronic spin multiplicity of the molecule or ion. This quantum
11 of energy can be in the form of an emission of a photon or transfer of energy to a neighboring
12 molecule or ion. A lumiphore is a molecule or ion or complex capable of luminescence, i.e.
13 any process by which an electron of a molecule or ion absorbs the energy contained in one or
14 more photons, with the result that this electron is elevated to a higher energy singlet state, sub-
15 sequently relaxes to a lower energy triplet state, and subsequently energy is lost from an elec-
16 tron of this molecule or ion in the form of a quantum of energy with the concurrent
17 deactivation of this electron to a lower state. This process involve a change of the electronic
18 spin multiplicity of the molecule or ion. This quantum of energy can be in the form of an
19 emission of a photon or transfer of energy to a neighboring molecule or ion.

20 The solvent has an evaporation rate preferably at least equal to that of water. The amount of
21 solvent is sufficient to afford a unitary solution.

22 In the unitary luminescence enhancing solution, the concentration of surfactant, when
23 present, is less than the critical micellar concentration.

24 Also in accordance with this invention, there is provided a spectrofluorimetrically detect-
25 able solid luminescent composition consisting essentially of:

26 A spectrofluorimetrically detectable luminescent resonance energy transfer (from here on
27 abbreviated RET) transparent solid composition consisting essentially of a processed speci-
28 men which includes at least one conjugate of a lanthanide ion complex and is embedded in a
29 luminescence enhancing solid composition derived by removal of the solvent from the unitary
30 luminescence enhancing solution. This labeled specimen containing composition consists of

31

1 at least one energy transfer acceptor lanthanide ion complex having an emission spectrum
2 with at least one maximum in the range from 300 to 2000 nanometers, and a luminescence-
3 enhancing amount of at least one fluorophore and/or lumiphore energy transfer donor with the
4 condition that the emission spectrum of the energy transfer donor differs from that of the
5 energy transfer acceptor lanthanide ion complex.

6 The term "consisting essentially of" is used in its art-recognized sense to express that the
7 composition is open to the inclusion of only such additional ingredients as do not adversely
8 affect its essential properties as defined. Consequently, the presence of a surfactant in a con-
9 centration that, when the composition is liquid, is greater than the critical micelle concentra-
10 tion, is excluded, because surfactant in such concentration impairs the morphology of delicate
11 objects, such as mammalian cells.

12 The enhanced luminescence of compositions according to the invention permits the detec-
13 tion and/or quantitation of the conjugates of lanthanide ion complexes with or without the use
14 of time-gated detection systems. As a result, these lanthanide ion complexes are useful as
15 optical-labels for analysis and quantitation. Areas of use include but are not limited to: immu-
16 noassays; genomics; proteomics; cytomics; analytical cytology; histological staining; arrays
17 of nucleic acids, proteins, and tissue sections; and imaging processing. Accordingly, there is
18 also provided, according to this invention, a method for analysis of an insoluble or insolubi-
19 lized sample suspected of containing at least one analyte, frequently a biologically active
20 compound, the method comprising the steps:

- 21 (a) Contacting the sample with a solution that contains an energy transfer acceptor lan-
22 thanide ion complex which is conjugated to an analyte-binding species. This conjugation
23 to the analyte-binding species can be achieved either directly or indirectly through a
24 bridging molecule, and/or by being a label of a labeled-polymer-conjugate of said mem-
25 ber;
- 26 (b) Incubating the sample with the solution under binding conditions, whereby the mem-
27 ber of the specific combining pair binds to the analyte;
- 28 (c) Usually washing the sample to remove the unbound conjugate of the member of a
29 specific combining pair;
- 30

1 (d) Adding to the sample a unitary luminescence enhancing solution;

2 (e) Removing the solvent of the unitary luminescence enhancing solution to produce a
3 homogeneous solid composition that includes both the energy transfer donor compound
4 and the energy transfer acceptor complex;

5 (f) Subjecting the homogeneous solid composition to excitation energy in the range of
6 200-1500 nm, whereby enhanced luminescence in the range of 350-2000 nm is gener-
7 ated;

8 (g) Monitoring the luminescence of the homogeneous solid composition for at least one
9 of the following:

10 (1) presence and/or concentration and/or location of the energy transfer
11 acceptor lanthanide ion complex; and

12 (2) presence and/or concentration and/or location of the product of the
13 interaction of the analyte with the energy transfer acceptor lanthanide ion
14 complex which is conjugated to an analyte-binding species.

15 There is, moreover, provided a method for analysis of a first solution suspected of contain-
16 ing at least one analyte, frequently a biologically active compound, comprising the steps

17 (a) Binding a member of a specific combining pair that is specific to an analyte to a
18 receiving surface member;

19 (b) Washing the receiving surface member to remove any unbound member of a specific
20 combining pair;

21 (c) Adding a first known volume of a first solution to a second known volume of a sec-
22 ond solution that contains an energy transfer acceptor lanthanide ion complex which is
23 conjugated to an analyte. This conjugation to the analyte can be achieved either directly
24 or indirectly through a bridging molecule, and/or by being a label of a labeled-polymer-
25 conjugate of the member;

26 (d) Incubating the combined solutions under binding conditions with the solid support,
27 whereby the member of the specific combining pair binds to the analyte;

1 (e) Usually washing the solid support to remove the unbound analyte and analyte conju-
2 gate of the energy transfer acceptor lanthanide ion complex;

3 (f) Adding to the sample a unitary luminescence enhancing solution;
4

5 (g) Removing the solvent of the unitary luminescence enhancing solution to produce a
6 homogeneous solid composition that includes both the energy transfer donor compound
7 and the energy transfer acceptor complex;

8 (h) Subjecting the homogeneous solid composition to excitation energy in the range of
9 200-1500 nm, whereby enhanced luminescence in the range of 350-2000 nm is gener-
10 ated;

11 (i) Monitoring the luminescence of the homogeneous solid composition to measure the
12 decrease in the emission intensity resulting from the competition of the unconjugated
13 analyte with the conjugated analyte.
14

15 The unitary luminescence enhancing solutions according to the invention are conveniently
16 termed unitary resonance energy transfer (RET), and when they include a complex of a sec-
17 ond lanthanide ion, they are termed columinescence solutions. Such solutions can be directly
18 integrated into standard histochemical and cytochemical processing. Such solutions can also
19 be dried to afford solids which can be stored for desired periods, or they can be packaged ini-
20 tially as solids and later reconstituted as effective solutions by combination with solvent at the
21 time of use.

22 The enhanced luminescence of the lanthanide ions and complexes thereof in the solid state,
23 resulting from the use of either RET or its derivative, columinescence, solutions according to
24 the invention, is believed to be caused by the absorption of one or more photons by an energy
25 transfer donor.

26 and by the transfer of all or part of the absorbed energy to an energy transfer acceptor lan-
27 thanide ion complex that subsequently emits all or part of this energy as a photon, with the
28 limitation that less than twenty percent of any light emitted by the energy transfer donor com-
29 pound or ion overlaps in the wavelength with the light emitted by the lanthanide energy trans-
30 fer acceptor complex.

31

1 In the Resonance Energy Transfer or its derivative, cofluorescence, of the invention, the
2 energy transfer acceptor can be a functionalized derivative of an energy transfer acceptor lan-
3 thanide ion complex, that is, a complex substituted with reactive functional groups at which
4 reaction with a member of a specific combining pair can take place; the energy transfer accep-
5 tor can also be a reaction product of such functionalized lanthanide ion complex with such
6 analyte; or a polymer which contains one or more lanthanide-ion-containing complex units.

7 There is also provided, in accordance with this invention, a dry mixture consisting essen-
8 tially of an energy transfer donor fluorophore or lumiphore, or a combination thereof; and an
9 organic and/or biological material to which is linked through a reactive functionality an
10 energy transfer acceptor lanthanide ion complex, provided that the lanthanide ion and a metal
11 ion, if present in the donor, are not the same. Since this dry mixture is not diluted with one or
12 more materials to an extent resulting in separation of the energy transfer donors from the
13 energy acceptor lanthanide ion complex, the dried solids including the energy transfer donors
14 act as the host material and provide the energy to the energy transfer acceptor. Since the
15 energy transfer donor molecule, ion, and/or complex of the metal ion, while in solution, con-
16 tacts and if necessary is given time to penetrate into organic and/or biological material before
17 it is dried, the concentration of donor molecule, ion, and/or complex near the acceptor lan-
18 thanide ion complex can be much higher than that provided by a unitary solution. In the limit-
19 ing case, the acceptor lanthanide ion complex is present at a minuscule concentration
20 compared to that of the energy transfer donor.

21 It is a feature of this invention that the method does not require prior dissociation of the
22 luminescence-enhanced complex before measuring its emission. Moreover, since the excita-
23 tion spectra of lanthanide ion complexes and those of several DNA-specific fluorophores,
24 including 4',6-diamidino-2-phenylindole (DAPI), occur in the same region of the ultraviolet,
25 both types of compounds can be excited at the same wavelength, while their emission spectra
26 occur in different regions. The organic fluorophores have broad emissions in the blue region
27 of the spectrum with short lifetimes, whereas the enhanced luminescence of lanthanide ion
28 complexes according to this invention occurs as very narrow emission peaks in the green,
29 orange, red, and infrared region of the spectrum with long lifetimes. This difference allows the
30 major emission of the enhanced luminescence composition of this invention to be unambigu-

1 ously detected even when its intensity is much lower than that of the very strong emission of
2 the DNA-specific or other organic fluorophores.

3 It is a further feature of the invention that the composition and method of the invention not
4 only provide enhanced luminescence but also minimize the interfering effect of the non-spe-
5 cific binding of lanthanide macrocyclic complexes to substrates.

6

7 DETAILED DESCRIPTION OF THE INVENTION INCLUDING PREFERRED
8 EMBODIMENTS

9

10 DESCRIPTION OF PREFERRED EMBODIMENTS

11 Unless defined otherwise, all technical and scientific terms used herein have the same
12 meaning as commonly understood to one of ordinary skill in the art to which this invention
13 belongs. Although any methods, devices and materials similar or equivalent to those
14 described herein can be used in the practice or testing of the invention, the preferred methods,
15 devices and materials are now described.

16 All patents and publications mentioned herein are incorporated herein by reference for the
17 purpose of describing and disclosing, for example, the cell lines, constructs, and methodolo-
18 gies that are described in the patents and publications, which might be used in connection with
19 the presently described invention. The patents and publications discussed throughout the text
20 are provided solely for their disclosure prior to the filing date of the present application. Noth-
21 ing herein is to be construed as an admission that the inventors are not entitled to antedate
22 such disclosure by virtue of prior invention.

23

24 **ACCEPTORS**

25 The energy transfer acceptor lanthanide complex ingredient of the composition of the
26 invention is characterized by a luminescence spectrum with emission in the range from 300 to
27 2,000 nanometers and preferably from 350 to 1500 nanometers, following excitation in the
28 range from 200 to 1800 nanometers and preferably from 200 to 1600 nanometers. This excita-
29 tion can be from one or more photons.

29

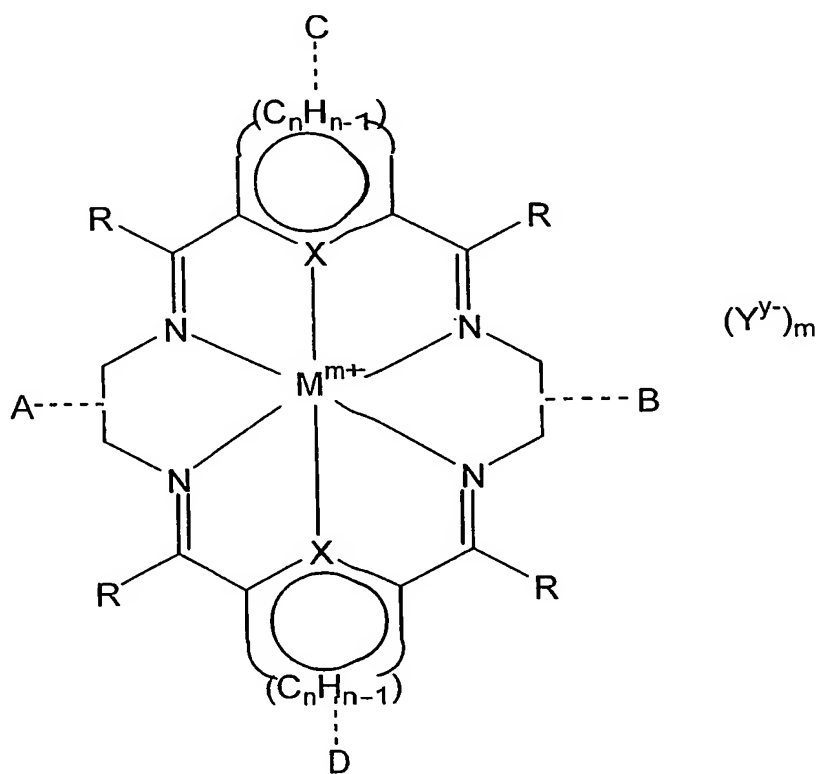
30 When the energy transfer acceptor lanthanide complex ingredient of the composition of the
31 invention is a macrocycle, it is characterized by kinetic stability even in very dilute aqueous

31

1 solution. The complex is resistant to removal or exchange of the central metal and has counte-
 2 rions, or charge-balancing anions, readily exchangeable by other anions.

3 The macrocycle moiety of the lanthanide energy transfer acceptor macrocyclic complex
 4 has six coordinating atoms, of which at least 4 are nitrogen atoms, and the remainder are nitro-
 5 gen, oxygen, or sulfur.

6 In particularly preferred compositions of the invention, the lanthanide energy transfer
 7 acceptor macrocyclic complex has the formula



Formula III

Wherein:

M is a metal ion selected from the group consisting of a lanthanide having atomic number 57-71, an actinide having atomic number 89-103, and yttrium having atomic number 39;

R is a substituent selected from the group consisting of hydrogen, straight-chain alkyl or branched-chain alkyl; aryl-substituted alkyl, aryl, or alkyl-substituted aryl, with the

1 proviso that such substituent does not limit the solubility of the resultant complex or
2 otherwise interfere with the cyclization of such complex during its synthesis;

3 X is an atom selected from the group consisting of nitrogen, sulfur and oxygen; such
4 atom forms a part of a ring structure selected from the group consisting of pyridine,
5 thiophene or furan, respectively;

6 n is 2 or 3;

7 Y is a negatively charged ion, including acetate, carboxylate, sulfonate, halide, nitrate,
8 perchlorate, thiocyanate, and picrate, with the proviso that such negative ion does not limit the
9 solubility of the resultant complex or otherwise interfere with either the coupling procedure or
10 the energy transfer leading to luminescence;

11 m+ is the ionic charge of the metal ion in the macrocyclic complex, and;

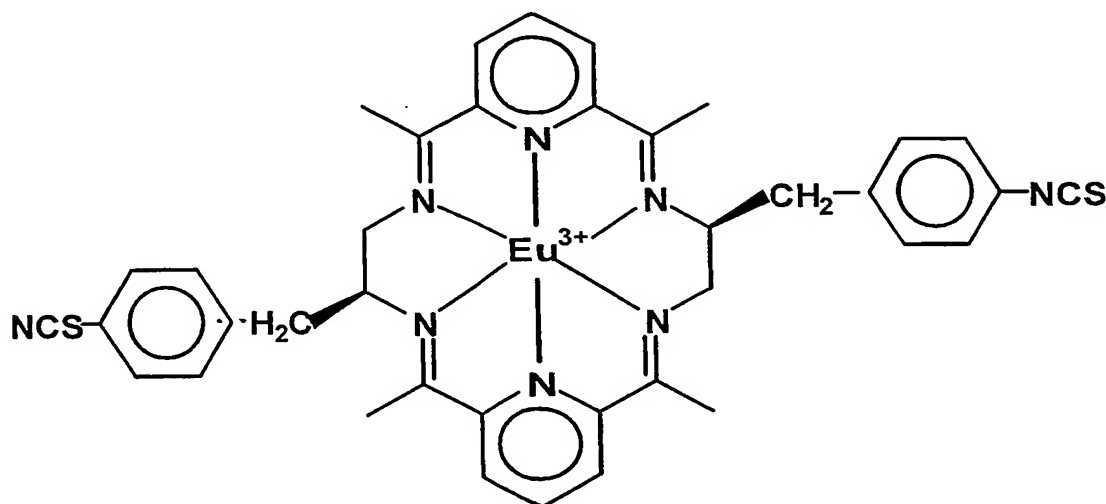
12 y- is the ionic charge of the counterion in the macrocyclic complex.

13 A, B, C, and D are substituents selected from the group consisting of hydrogen,
14 straight-chain alkyl or branched-chain alkyl; aryl-substituted alkyl, aryl, or alkyl-sub-
15 stituted aryl; reactive functionality, functionalized alkyl, functionalized aryl-substi-
16 tuted alkyl, functionalized aryl, or functionalized alkyl-substituted aryl. Straight chain
17 and branched chain alkyl substituents at A, B, C, and/or D have from 1 to 25 carbon
18 atoms. The reactive functionality is thereby spaced from the macrocycle as desired.
19 Further illustrative functionalized substituents include hydroxymethyl, 4-hydroxyben-
20 zyl, 4-aminobenzyl, and 4-isothiocyanatobenzyl.
21

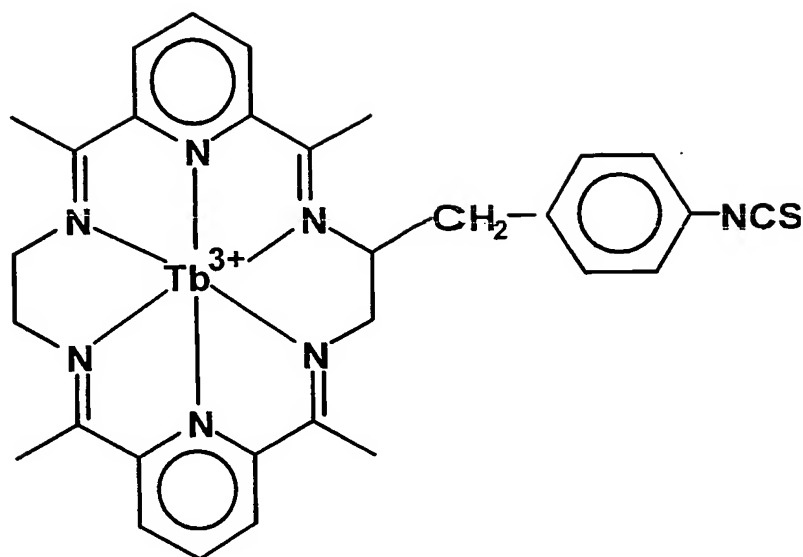
22 For convenience, the following abbreviations can be used to refer to compounds of Formula
23 III.

24 Any and all of the metal ions selected from the group consisting of a lanthanide having
25 atomic number 57-71, an actinide having atomic number 89-103, and yttrium having atomic
26 number 39 will have M as their abbreviation. Specific metal ions will be given as their stan-
27 dard chemical symbols. The unfunctionalized, mono-functionalized and di-functionalized
28 macrocyclic complexes will be abbreviated respectively as "Mac-un", "Mac-mono" and
29 "Mac-di". The term "Macs" without the -un, -mono, or -di suffix will include the unfunction-
30 alized, mono-functionalized and di-functionalized macrocyclic complexes (Mac-un, Mac-
31 mono and Mac-di). When a specific peripheral pendant substituent having at least one reactive

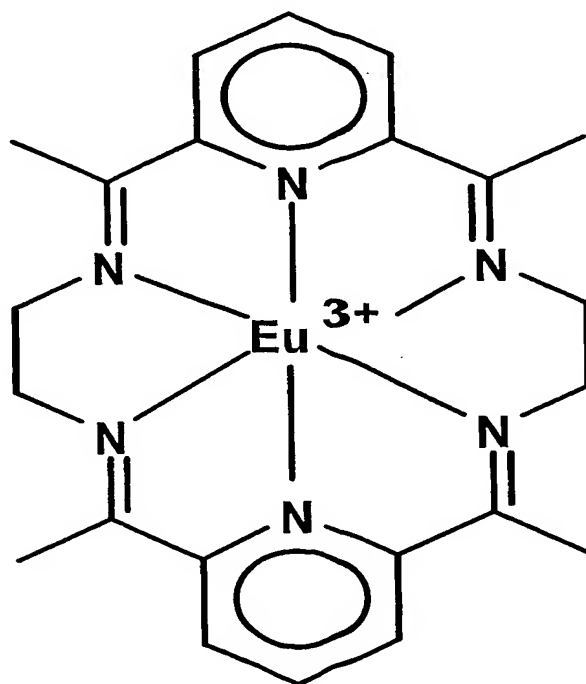
1 site (reactive functionality) is mentioned, its abbreviation will be given as a suffix. Thus the
2 compound of Formula IV shown below, in which M is europium, each R is methyl (as shown
3 by bond lines without termination) and each of A and B is a 4-isothiocyanatobenzyl group, is
4 abbreviated as EuMac-di-NCS. The compound of Formula V shown below, in which M is ter-
5 bium, each R is methyl, and B is a 4-isothiocyanatobenzyl group, is abbreviated as TbMac-
6 mono-NCS, and the unfunctionalized compound of Formula VI shown below, in which M is
7 europium, each R is methyl and each of A and B is hydrogen, is abbreviated as EuMac-un.



18 Formula IV. Schematic formula of a di-functionalized europium macrocyclic complex.
19 This structure is one of the isomers of the cationic europium macrocyclic moiety contain-
20 ing a 4-isothiocyanato-benzyl- substituent on each of the aliphatic side-chains. The
21 molecular formula of the moiety is C₃₈H₃₆N₈S₂Eu. This formula, and the following formu-
22 lae that include methyl groups, adhere to the present convention of showing methyl
23 groups as bond lines without termination.



Formula V. Schematic formula of a cationic mono-functionalized terbium macrocyclic complex containing a 4-isothiocyanato-benzyl-substituent on one of the aliphatic side-chains. The molecular formula of the moiety is $C_{30}H_{31}N_7STb$.



Formula VI. Schematic formula of a cationic unfunctionalized europium macrocyclic complex. This structure is the unfunctionalized prototype, EuMac-un.

For the synthesis of these lanthanide macrocycle complexes, including access to the required starting materials, reaction conditions, purification, and subsequent coupling reac-

1 tions with compounds of biological interest, reference can be made to Vallarino et al., Patents
2 5,373,093 and 5,696,240 herein incorporated by reference.

3 In a preferred group of compositions of this invention, at least one of the substituents A, B,
4 C, and D of Formula III is a reactive functionality or a functionalized alkyl, functionalized
5 aryl-substituted alkyl, functionalized aryl, or functionalized alkyl-substituted aryl group.
6 Through these substituent groups, coupling or noncovalent binding can take place with an
7 analyte, which can be a biologically active compound or any other compound able to interact
8 with a functionalized substituent at A, B, C, and/or D.

9 Such coupling can take place directly, as in a conjugate of a LnMac with a protein or a
10 polynucleotide linked to the LnMac through a functionalized group at A, B, C, or D.

11 Coupling of a functionalized group at A, B, C, or D with an analyte can also take place
12 indirectly, by reaction between the functionalized group and a bridging/linking moiety that
13 provides the capability for derivatization with a receptor molecule or with an entity for which
14 there is a corresponding receptor molecule, together with controlled spacing of the substrate
15 of biological interest relative to the macrocycle of Formula III. Thus coupling is accomplished
16 indirectly, either by the use of a bifunctional crosslinking reagent that provides covalent bind-
17 ing to the substrate of biological interest, or by binding the macrocycle to another molecule
18 that has a high affinity for the substrate. To illustrate, streptavidin can couple with a function-
19 alized macrocycle as well as with biotin, thus providing a link between biotin and the LnMac.
20 In another illustrative reaction, an amine-functionalized macrocyclic complex of Formula III
21 is acylated with a reagent, such as succinic anhydride, to provide a carboxyl group which then
22 readily either bind to the free amino groups of lysine in proteins, forming a protein/macrocyc-
23 cle conjugate or can through the known art (Ref. 28) be transformed into a different reactive
24 functionality, such as a NHS ester.

25 The lanthanide macrocycle complexes with more than one reactive functionality, such as
26 the EuMac-di-NCS, can be used as both labels and cross-linking fixatives. They can be used
27 to optically label and immobilize proteins and other macromolecules, including those present
28 in gels after electrophoretic separation.

29 Other applications include fingerprint detection.

30

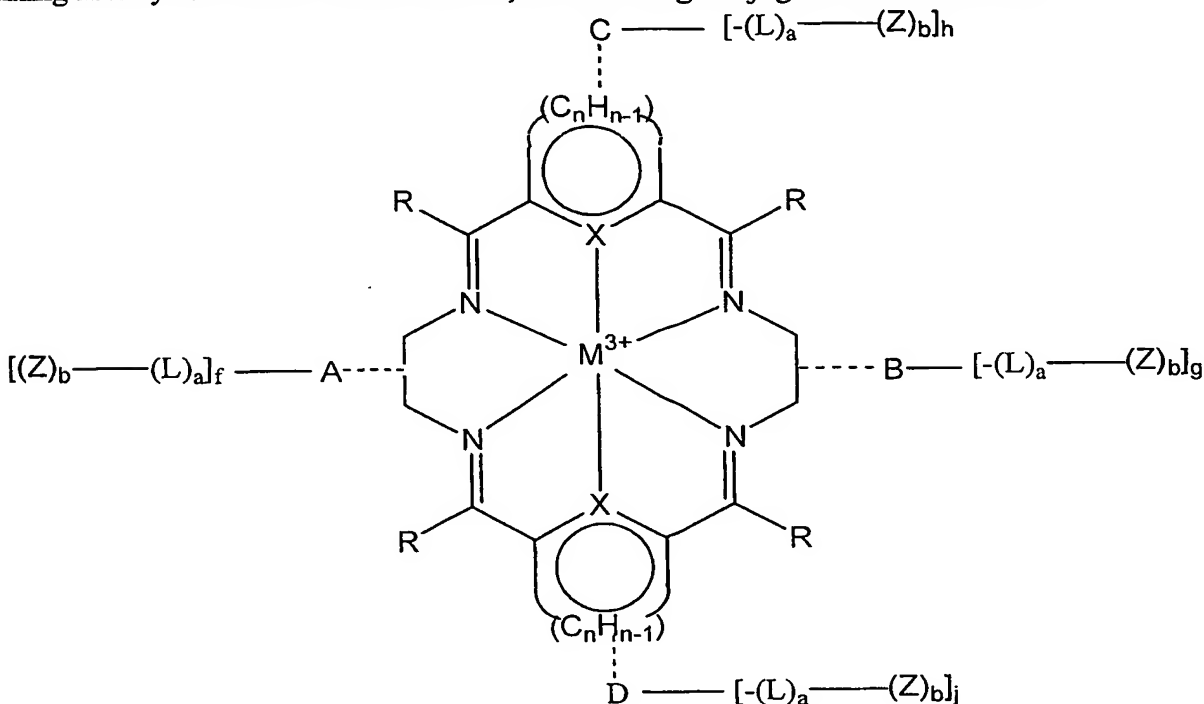
31

1 In a particularly preferred embodiment, a composition of the invention can include two dif-
2 ferent LnMacs energy transfer acceptors, both coupled to the same polynucleotide, or two dif-
3 ferent LnMacs energy transfer acceptors, each coupled to a different polynucleotide, having in
4 each case luminescence enhanced according to the invention. When the two LnMacs differ in
5 their central metal ion, as with an europium macrocycle and a samarium macrocycle, and
6 hence differ in the wavelength of their emission peaks, the measurement of the intensity of
7 each peak provides a measure of the concentration of each LnMac and, if both LnMacs are
8 present, it also provides their relative ratios over a range from 500:1 to 1:500, more specifi-
9 cally over a range from 100:1 to 1:100.

10
11 An important application of the above effect is the measurement of relative concentrations
12 of normal cell DNA and cancer cell DNA by coupling each of these to a different LnMac.

13 For further details of the coupling capabilities of functionalized macrocycles of Formula
14 III, reference can be made to Vallarino et al. Patent 5,696,240, at column 21 line 52 to column
15 22 line 42, here incorporated by reference.

1 When a functionalized macrocycle of Formula III is coupled directly or through a bridging/
 2 linking moiety to a reactive biomolecule, the resulting conjugate has the formula



17 in which M, X, R, and n are as defined above; from one to two of A, B, C, and D are func-
 18 tionalized groups as defined above, and the remaining groups of A, B, C, and D are selected
 19 from the group consisting of hydrogen, straight-chain alkyl, branched-chain alkyl, aryl-substi-
 20 tuted alkyl, aryl, and alkyl-substituted aryl; L is a bridging/linking moiety between the func-
 21 tionalized macrocycle and a biologically active compound, Z is a residue of a biologically
 22 active compound linked to L, a is zero or one, b is one, and each of f, g, h, and j is indepen-
 23 dently zero or one, provided that the sum of f, g, h, and j is either one or two.

24 When a functionalized macrocycle of Formula III is coupled to a bridging/linking moiety
 25 with the capability of further reacting with an analyte to form a conjugate, the resulting com-
 26 plex has Formula VII in which L is a bridging/linking moiety capable of coupling the func-
 27 tionalized macrocycle and the analyte, a is one and b is zero, and M, X, R, n, A, B, C, D, f, g,
 28 h, and j are as defined above.

29 As a result of the ability of analytes including reactive biomolecules to form a covalent
 30 bond with a functionalized macrocycle in a composition of this invention, as expressed by Z
 31 in Formula VII, the enhanced luminescence of the composition can serve as an analytical tool

1 for estimating such biomolecules as analytes. Thus the analyte can be any compound of inter-
2 est, naturally occurring or synthetic, for which there exists a complementary binding partner.

3 These analytes are conveniently grouped by molecular weights. One group of such ana-
4 lytes consists of compounds that have molecular weights in the range of about 125-2,000 dal-
5 tons and include a wide variety of substances, which are often referred to as haptens. These
6 compounds include:

- 7 (a) Vitamins, vitamin precursors, and vitamin metabolites including retinol, vitamin
8 K, cobalamin, biotin, folate;
9
- 10 (b) Hormones and related compounds including
 - 11 (i) steroid hormones including estrogen, corticosterone, testosterone, ecdysone,
 - 12 (ii) aminoacid derived hormones including thyroxin, epinephrine,
 - 13 (iii) prostaglandins,
 - 14 (iv) peptide hormones including oxytocin, somatostatin;
 - 15
- 16 (c) Pharmaceuticals including aspirin, penicillin, hydrochlorothiazide;
17
- 18 (d) Nucleic acid constituents including
 - 19 (i) natural and synthetic nucleic acid bases including cytosine, thymine, adenine,
 - 20 guanine, uracil, derivatives of said bases including 5-bromouracil,
 - 21
 - 22 (ii) natural and synthetic nucleosides and deoxynucleosides including 2-deoxyad-
23 enosine, 2-deoxycytidine, 2-deoxythymidine, 2-deoxyguanosine, 5-bromo-2-
24 deoxyuridine, adenosine, cytidine, uridine, guanosine, 5-bromo-uridine,
 - 25 (iii) natural and synthetic nucleotides including the mono, di, and triphosphates of
26 2-deoxyadenosine, 2-deoxycytidine, 2-deoxythymidine, 2-deoxyguanosine, 5-
27 bromo-2-deoxyuridine, adenosine, cytidine, uridine, guanosine, 5-bromo-
28 uridine;
- 29 (e) Drugs of abuse including cocaine, tetrahydrocannabinol,
- 30 (f) Histological stains including fluorescein, DAPI;
- 31

1 (g) Pesticides including digitoxin;

2 (h) Miscellaneous haptens including diphenylhydantoin, quinidine, RDX.

3
4 Another group of analytes consists of compounds having a molecular weight of 2,000 dal-
5 tons or more, including

6 (a) Proteins and their combinations including

7
8 (i) albumins, globulins, hemoglobin, staphylococcal protein A, alpha-fetoprotein,
9 retinol-binding protein, avidin, streptavidin, C-reactive protein, collagen, ker-
10 atin,

11 (ii) immunoglobulins including IgG, IgM, IgA, IgE,

12 (iii) hormones including lymphokines, follicle stimulating hormone, and thyroid
13 stimulating hormone,

14 (iv) enzymes including trypsin, pepsin, reverse transcriptases, terminaldeox-
15 ytransferase,

16
17 (v) cell surface antigens on T- and B-lymphocytes, i.e. CD-4, CD-8, CD-20 pro-
18 teins, and the leukocyte cell surface antigens, such as described in the pres-
19 ently employed CD nomenclature,

20 (vi) blood group antigens including A, B and Rh,

21 (vii) major histocompatibility antigens both of class 1 and class 2,

22
23 (viii) hormone receptors including estrogen receptor, progesterone receptor, and
24 glucocorticoid receptor,

25 (ix) cell cycle associated proteins including protein kinases, cyclins, PCNA, p53,

26
27 (x) antigens associated with cancer diagnosis and therapy including BRCA(s)
28 carcinoembryonic antigen, HPV 16, HPV 18, MDR, c-neu; tumor suppressor
29 proteins, p53 and retinalblastoma,

30 (xi) apoptosis related markers including annexin V, bak, bcl-2, fas caspases,
31 nuclear matrix protein, cytochrome c, nucleosome,

(xii) toxins including cholera toxin, diphtheria toxin, and botulinum toxin, snake venom toxins, tetrodotoxin, saxitoxin,

(xiii) lectins including concanavalin, wheat germ agglutinin, soy bean agglutinin;

(b) Polysialic acids including chitin;

(c) Polynucleotides including

(i) RNAs including segments of the HIV genome, human hemoglobin A messenger RNA,

(ii) DNAs including chromosome specific sequences, centromeres, telomere specific sequences, single copy sequences from normal tissues, single copy sequences from tumors.

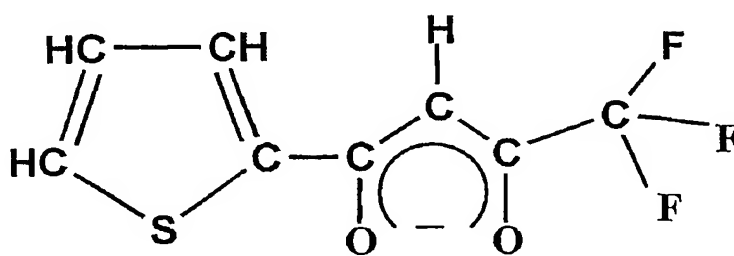
The biomolecule to be coupled to the macrocyclic complex for imaging or therapy is typically a species selected to carry out a specific target function. In one embodiment, the biomolecule is a monoclonal antibody or antibody fragment which is specific against a selected cell-surface target site. Such antibodies are commercially available, or are made by well-known techniques.

In a preferred embodiment, the lanthanide(III) of the energy transfer acceptor macrocyclic complex is europium, samarium, or terbium. In a particularly preferred embodiment, a composition of the invention includes an energy transfer acceptor macrocyclic complex in which the central ion is europium, a second energy transfer acceptor macrocyclic complex in which the central ion is terbium, and a third energy transfer acceptor macrocyclic complex in which the central ion is samarium. The characteristic emission peaks of the europium, terbium and samarium ions are sufficiently separated in the spectrum, so that the emission intensities of the three macrocyclic complexes can be measured in the presence of one another. As a result, three different biomolecules can be measured in the presence of one another by using an enhanced luminescence composition of the invention, whereby one biomolecule is coupled to a functionalized europium macrocycle, a second biomolecule is coupled to a functionalized terbium macrocycle, and a third is coupled to a functionalized samarium macrocycle.

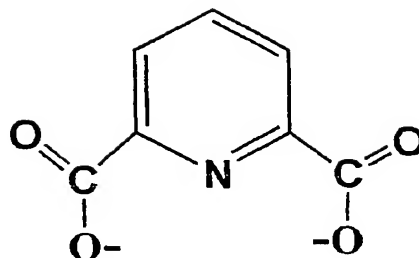
1 DONORS

2 The energy transfer donor transfers energy to the energy acceptor lanthanide complex. In a
3 preferred embodiment, this donor can be a fluorophore and/or lumiphore organic moiety
4 which upon excitation by a photon transfers energy to the lanthanide complex. An example of
5 this is HTTFA when present in molecular concentration excess relative to the energy acceptor
6 lanthanide complex. Alternatively, the energy transfer donor is a fluorophore and/or lumi-
7 phore ligand capable of being bound to a lanthanide metal ion or alternatively a fluorophore
8 and/or lumiphore ligand bound to a lanthanide metal ion, or a mixture thereof. These ligands
9 are characterized by electron donating atoms, such as oxygen, nitrogen, sulfur or phosphorus,
10 and are able to coordinate with the energy acceptor lanthanide(III) or with energy donor gado-
11 linium (III) or yttrium(III) ions. Preferred unbound or nonbinding fluorophore and/or lumi-
12 phore species include HTTFA or any other nonbinding species that has an extinction
13 coefficient above 5,000 at a wavelength between 200-800 nm for single photon excitation, and
14 twice those wavelengths (400-1600 nm) for two photon excitation.

15 Examples of fluorophore and/or lumiphore donors include HTTFA and H₂PDCA and the
16 anions TTFA, Formula VIII, and PDCA, Formula IX, resulting from deprotonation of these
17 molecules. Alternatively the fluorophore and/or lumiphore energy transfer donor can be a
18 ligand complex that includes a lanthanide(III). Examples of this are Gd(TTFA)₃ and
19 Na₃Gd(PDCA)₃.



Formula VIII



Formula IX

Non-limiting examples of energy transfer donors are the fluorophore and/or lumiphore ligands or anions formed in an acid-accepting environment by deprotonation of diketones, monocarboxylic and dicarboxylic acids and their esters, ortho-hydroxy-substituted aromatic carboxylic acids in which the oxygen atoms are positioned so as to favor homogeneous resonance energy transfer to the ligands that can form a chelate ring structure with the acceptor metal ion, and heterocyclic mono- and di-carboxylic acids in which the oxygen atoms of the carboxylate group and the heteroatom of the cyclic structure are positioned so as to favor formation of a chelate ring structure with the acceptor metal ion. Other non-limiting examples of energy transfer donors are the acids of these anionic ligands, having emissions that overlap the excitation of the energy acceptor lanthanide complex. Other non-limiting examples of energy transfer donors are the complexes of these ligands with metal ions. Preferably, these fluorophore and/or lumiphore donor metal ions are selected from the group of Gd(III), Y(III), Lu(III), and La(III). Alternatively under excitation which does not result in their emission, any of the acceptor lanthanide ions Eu(III), Sm(III), Tb(III) or Dy(III) can be employed. More preferably Eu(III) and Tb(III) can be employed.

The substitution of fluorine for hydrogen in the ligand further enhances the latter's effectiveness and removes a hydrogen atom that possibly could participate in loss of luminescence by radiationless vibrational transfer of the energy responsible for the luminescence to the surrounding solvent.

When the fluorophore and/or lumiphore ligand is a diketone, preferred ligand structures have the formula $RCX(CHR')_nCX\ddot{R}''$, in which:

R or R' or R'', independently at each occurrence, is an electron withdrawing group such as a hydroxy, an alkyl, a carbocyclic aromatic or heterocyclic aromatic group, a fluoroalkyl, flu-

1 fluoroalkylaryl, fluoroaryl, or fluoro-substituted heterocyclic aromatic group having 1 to 24 carbon atoms or R' is a hydrogen;

3 The concentration of these compounds or their anions, when present in the unitary luminescence enhancing solution, can range from 1×10^{-1} to 1×10^{-5} moles/L.

5 Preferred fluorophore and/or lumiphore beta-diketones have the formula $\text{RCOCH}_2\text{COR}'$ in which R or R' are a alkyl, fluoroalkyl, fluoroalkylaryl, or fluoroaryl, a carbocyclic or heterocyclic aromatic group having 1 to 11 carbon atoms. Particularly preferred beta-diketones are thenoyltrifluoroacetone and hexafluoroacetylacetone. The concentration of beta-diketone, when present in the unitary luminescence enhancing solution, can range from 1×10^{-2} to 1×10^{-5} moles/L.

12 Preferred fluorophore and/or lumiphore carboxylic acids include phthalic acid, furan-2-carboxylic acid, thiophene-2-carboxylic acid, pyridine-2-carboxylic acid (picolinic acid), furan-2,5-dicarboxylic acid, thiophene-2,5-dicarboxylic acid, pyridine-2,6-dicarboxylic acid and their lower alkyl esters, or any other carboxylic acid that has an extinction coefficient above 5,000 at a wavelength between 200-800 nm for single photon excitation, and at twice those wavelengths (400-1,600 nm) for two photon excitation.

18 Preferred fluorophore and/or lumiphore hydroxy-substituted aromatic carboxylic acids include salicylic acid and 2-hydroxynaphthalene-3-carboxylic acid.

20 Accordingly, the composition of the invention produces enhanced luminescence by the interaction in the solid state of an energy transfer acceptor lanthanide(III) macrocycle complex, as defined above, with a luminescence-enhancing amount of at least one fluorophore and/or lumiphore energy transfer donor. When the donor is an organic multidentate ligand, it can be combined in an acid-accepting environment with a metal ion to form a simple salt or a complex. The metal ion can be yttrium(III) or a 3-valent lanthanide having atomic number 59-71, preferably yttrium, lanthanum, or gadolinium. The metal ion, together with the atoms of the organic multidentate ligand to which it is coordinated, constitutes one or more five or six membered chelate ring structures.

29 The acid-accepting environment can be provided by any convenient inorganic or organic base such as an alkali metal base, an amine base, or a quaternary ammonium base. Suitable

1 bases include potassium hydroxide, potassium bicarbonate, triethylamine, triethanolamine,
2 tetramethylammonium hydroxide, and ammonia.

3 The organic multidentate ligand in an acid-accepting environment can also be provided as
4 separate ingredients of the composition of the invention, such as the ligand admixed with an
5 organic or inorganic base in stoichiometric, excess (super-stoichiometric) or deficient (sub-
6 stoichiometric) molecular proportions.

7 The energy transfer donor is soluble in a solvent affording a unitary solution with the other
8 components of the composition of the invention, as more fully defined below. The solvent is
9 preferably an alcohol, more preferably ethanol.

10 The fluorophore and/or lumiphore energy transfer donor in the composition is present in a
11 molecular concentration greater than that of the energy transfer acceptor complex. The con-
12 centration of the energy transfer donor in the unitary luminescence enhancing solution of the
13 invention can range from 1×10^{-1} to 1×10^{-5} moles/L.

14
15 In a preferred composition according to the invention, the fluorophore and/or lumiphore
16 energy transfer donor compound is an ionic compound of, or a complex of, gadolinium(III) or
17 yttrium(III). The gadolinium(III) or yttrium(III) complexes with organic multidentate ligands
18 are particularly preferred.

19 SOLVENT

20 As a liquid, the composition of the invention includes a solvent in an amount sufficient to
21 dissolve all the components forming a unitary solution of such concentration that after evapo-
22 ration the presence of the original solutes will increase the luminescence of the energy transfer
23 acceptor lanthanide(III) complex. The solvent has an evaporation rate at least as great as that
24 of water, to assure the ability to remove the solvent without special equipment and to obtain a
25 dry composition containing a modest level of residual solvent that does not interfere with the
26 luminescence of the composition, preferably less than 10% by weight, more preferably less
27 than 1% by weight.

28 Suitable organic solvents include acetone, aliphatic alcohols having 1 to 3 carbon atoms,
29 ethers such as 1,2-dimethoxyethane and 1,4-dioxane, and mixtures thereof. Methanol and eth-
30 anol are particularly preferred. Water can also be used as a solvent. The choice of solvent
31 depends on maintenance of the desired physical characteristics of the specimen after evapora-

1 tion. These include but are not limited to the morphology of microscopic objects and to the
2 physical distribution of the enhanced luminescence ingredients on the surface of a support
3 used in a measurement process.

4 **OTHER INGREDIENTS**

5 The composition of the invention can include a buffer to maintain the pH within a desired
6 range. Frequently used and preferred buffers include tris(hydroxymethyl)aminomethane, hex-
7 amethylenetetramine, and less preferred buffers include sodium and potassium bicarbonates.

8 The composition of the invention can include a high boiling liquid as an auxiliary solvent
9 used in small amounts to assist in the conversion of the composition to the dry state without
10 harmful effect. Such auxiliary solvents include toluene, xylene, pyridine, and polyethylene
11 glycols such as PEG 1450.

12 The composition of the invention can include one or more solids to enhance the lumines-
13 cence and/or maintain the desired physical and optical characteristics of the specimen after
14 evaporation. Auxiliary solids that maintain the desired physical and optical characteristics by
15 being crystallization inhibitors, and/or film formers, or binders include bovine serum albumin,
16 polyvinyl alcohol, polyvinylpyrrolidone, solid polyethylene glycols, and plasticizers. Auxil-
17 iary solids that enhance the luminescence by being synergistic ligands include trioctylphos-
18 phine oxide and 1,10-phenanthroline.

19 In a preferred embodiment, the invention can include coatings that are applied subsequent
20 to the formation of the homogeneous solid composition. These coatings include any transpar-
21 ent material that will transmit the excitation wavelengths and the emission wavelengths.
22 These coatings should not dissolve an amount of any component of the unitary luminescence
23 enhancing solution sufficient to make a significant reduction in the luminescence. In the case
24 of analyses that involve imaging, the refractive index of the coating shall be sufficiently close
25 to the refractive index of the specimen composition as to not significantly lower the optical
26 resolution. These coatings include commercial dried mounting media, such as Clearium and
27 solutions in organic solvents of plastics such as cyclo-olefins and acrylic polymers.

28 **FUNCTIONALIZED ACCEPTOR**

29 The reaction medium in which a sample containing or suspected of containing an analyte is
30 contacted with a functionalized complex according to this invention is preferably an aqueous
31

1 solution in which the presence of foreign materials such as salts or organic solvents is limited
2 to such concentrations as are tolerated by the analyte without denaturation, degradation, coag-
3 ulation, hydrolysis, polymerization or other interfering changes. Binding conditions include
4 such conditions of temperature, pressure, and pH as favor the reaction of the analyte with the
5 functionalized macrocyclic complex, preferably a temperature in the range from 10° C to 45°
6 C, a pressure in the range from 800 to 1000 millibars, and in solutions where pH can be accu-
7 rately measured, a pH in the range from 5.5 to 8.5.

8 The functionalized metal ion complex according the method of the invention is character-
9 ized by kinetic stability even in very dilute aqueous solution. The complex is resistant to
10 removal or exchange of the central metal ion, and has counterions or balancing anions. Prefer-
11 ably the central metal ion is a lanthanide ion; and preferably the ligand of the complex is a
12 macrocycle or a cryptate.

13 **SUPPORTS AND CONTAINERS**

14 The solid composition of the invention is preferably obtained by evaporation of a unitary
15 solution of the energy transfer donor, solvent, and any other required components thereof.
16 Evaporation suitably takes place in the presence of a support functioning as a container and/or
17 vessel for the production of enhanced luminescence in the amount required for monitoring
18 and measurement according to this invention. Suitable supports and containers include receiv-
19 ing surface members, such as microscope slides, cover-slips, and optical films or ribbons;
20 microtiter wells; microtiter plates or strips; centrifuge tubes; test tubes; cuvettes; plated sur-
21 faces; and embossed surfaces.

22 In a preferred embodiment, the supports and containers are coated with one or more mem-
23 bers from specific combining pairs that bind to an analyte or analyte-binding species. These
24 coating include but are not limited to biotin, antibodies, nucleic acids, haptens, and polysac-
25 charides.

26 **USING ENHANCED LUMINESCENCE COMPOSITIONS IN ANALYSIS OF CON-** 27 **JUGATES OF LANTHANIDE ION COMPLEXES**

28 In analyzing in accordance with the invention, a processed specimen containing or sus-
29 pected of containing an analyte is contacted with a solution that contains an energy transfer
30 acceptor lanthanide(III) complex that is conjugated to an analyte-binding species in preferably
31 an aqueous solution in which the presence of foreign materials, such as salts or organic sol-

1 vents, is limited to such concentrations as are tolerated by the analyte under binding condi-
2 tions without denaturation, degradation, coagulation, hydrolysis, polymerization or other
3 interfering changes. Binding conditions include such conditions of temperature, pressure, and
4 pH as favor the reaction of the analyte with the functionalized macrocyclic complex, prefera-
5 bly a temperature in the range from 10° C to 45° C, a pressure in the range from 800 to 1000
6 millibars, a pH in the range from 5.5 to 8.5.

7 The functionalized energy transfer acceptor lanthanide(III) complex according to the
8 invention is characterized by kinetic stability even in very dilute aqueous solution. The com-
9 plex is resistant to removal or exchange of the central lanthanide(III), and has counterions or
10 balancing anions readily exchanged for other anions. A detailed description of energy transfer
11 acceptor lanthanide(III) complexes is given above in the description of the Acceptors section
12 of the Prior Art. Preferably the ligands of the complex are functionalized macrocycles (Refs.
13 1,2) or functionalized cryptands (Refs. 24,25,26) particularly preferably are the functionalized
14 macrocycles of US patents 5,373,093 and 5,696,240.

15 The lanthanide(III), Ln(III), labeled processed specimen is then washed with a buffered
16 aqueous solution to remove the excess of the conjugate of the energy transfer acceptor lan-
17 thanide(III) complex and prepared for treatment with the unitary luminescence enhancing
18 solution. This treatment consists of optional air drying and optional transfer to the solvent of
19 the unitary luminescence enhancing solution. For delicate material, such as mammalian cells,
20 this transfer often involves a series of washes of a graded mixture of water with or without
21 buffer and the solvent of the unitary luminescence enhancing solution.

22 The treated Ln(III)-labeled processed specimen is then reacted with "unitary luminescence
23 enhancing solution, which after evaporation of the solvent results in the specimen containing
24 composition, which is composed of the processed specimen embedded in the luminescence
25 enhancing solid. Preferably the specimen containing composition is a transparent thin film on
26 a support or container.

27 INSTRUMENTATION

28 A variety of instruments is commercially available according to this invention for monitor-
29 ing the presence and/or concentration of the conjugate of a functionalized macrocyclic metal
30 complex with an analyte; the presence and/or concentration of the product of the interaction of
31

1 a functionalized macrocyclic metal complex with a binding material; and the presence and/or
2 concentration of the product of the interaction of the conjugate with the binding material.

3 Time-gated fluorescence instrumentation can be used according to this invention; fluores-
4 cence instrumentation equipped with a continuous as opposed to pulsed light source can now
5 also be used as a result of this invention. Such instrumentation can include: a standard manual
6 or automated fluorescence microscope, a standard manual or automated fluorometer for read-
7 ing samples including but not limited to discrete wells, microtiter trays and strips, arrays on
8 microscope slides or other similar surfaces, and dipsticks. Also suitable is fluorescence instru-
9 mentation that measures multiple samples at a time, having a luminescence detection zone in
10 which multiple samples can be automatically positioned. Such instrumentation can include a
11 microtiter plate, strip, or microscope slide positioning system.

12 In a particularly preferred type of fluorescence instrumentation, the instrument includes the
13 capability to image the sample being analyzed, and especially to measure the analyte at vari-
14 ous points in the image. This can be accomplished in particular as the instrument measures,
15 records, processes, and/or displays the spatial distribution of one or more analytes. Instrumen-
16 tation with these capabilities include: the EIDAQ 100 - HTM manufactured by Q3DM 10110
17 Sorrento Valley Road, Suite B, San Diego, CA 92121; the Chromoscan manufactured by
18 Applied Imaging Corporation 2380 Walsh Avenue, Santa Clara, California 95051, and the
19 Axioplan 2 imaging manufactured by Carl Zeiss, Inc. One Zeiss Drive Thornwood, NY 10594.

20 Among the preferred time-gated and/or continuous light source fluorescence instruments
21 of these types can be mentioned a Varian Cary Eclipse spectrofluorometer (121 Hartwell Ave-
22 nue, Lexington, MA 02421), an Ocean Optics USB2000-FLG Spectrofluorometer (380 Main
23 Street, Dunedin, FL 34698), and a Jobin Yvon Inc. Fluorolog®-3 (3880 Park Avenue, Edison,
24 NJ 08820-3097).

25 Particularly preferred applications of the method include comparative genomic hybridiza-
26 tion and measurement of one or more samples for an analyte on a microarray.

27 In an important feature of the method of the invention, the enhanced luminescence compo-
28 sition of the invention is formed in a dry state by evaporation of the solvent from a preformed
29 unitary solution.

30

31

1 The following examples of compositions characterized by the use of energy transfer accep-
2 tor lanthanide complexes that are resistant to removal or exchange of the central metal ion,
3 and of the use of said compositions, together with the use of unitary luminescence enhancing
4 solutions and energy transfer donor complexes, are provided by way of illustration and not of
5 limitation of the invention, whose scope is defined by the appended claims.

6
7 Brief Description of the Drawings:

8 Figure 1 shows inverted images of the wells of a microtiter plate.

9 Figure 2 shows inverted images of the wells of a microtiter plate.

10 Figure 3 shows inverted images of the wells of a microtiter plate.

11 Figure 4 is a graphical presentation of the ultraviolet absorption spectra of the EuMac-
12 mono-NCS, streptavidin, and the EuMac coupled to streptavidin.

13 Figure 5 is a graph of the relative emission intensity versus the concentration of
14 streptavidin added to the biotinylated well.

15 Figure 6 is a plot the concentrations of $Gd(TTFA)_3$ and $HTTFA$ vs. relative lumines-
16 cence.

17 Figure 7 is a plot of the concentrations of $Gd(TTFA)_3$, $Na(TTFA)$, and their one-to-
18 one mixture vs. relative luminescence.

19 Figure 8 is a plot of the concentrations of $Gd(TTFA)_3$, $Na(TTFA)$, $HTTFA$, and their
20 mixtures vs. relative luminescence.

21 Figure 9a is a graph showing the effect of differing concentrations of $Na_2(PDCA)$ on
22 the luminescence of two different lanthanide macrocycles.

23 Figure 9b is a graph showing the effect of differing concentrations of $Na_3Gd(PDCA)_3$
24 on the luminescence of two different lanthanide macrocycles.

25 Figure 10 is a graphical presentation of the ultraviolet absorption spectra of the
26 EuMac-mono-NCS, anti-5-BrdU, and the EuMac coupled to anti-5-BrdU.

27 Figure 11 is a pair of inverted images of EuMac-di-NCS stained cells. A is a 5 second
28 exposure; B is the summation of 1000 time-gated images, each exposed for 2 msec.
29
30
31

Figure 12 shows four images of a single preparation of nonapoptotic cells stained with both EuMac-di-NCS and DAPI.

Figure 13 shows two inverted images of cells stained with SmMac-di-NCS and DAPI.

Figure 14 is an inverted image of directly stained apoptotic cells.

Figure 15 is an inverted image of EuMac-anti-5-BrdU stained cells in S phase.

Figure 16 is an inverted image of EuMac-Streptavidin stained apoptotic cells.

Figure 17 is an inverted image of EuMac-Streptavidin stained cells in S phase.

Figure 18 is an inverted image of two photon excited EuMac-di-NCS stained cells.

SUMMARY OF EQUIPMENT, INSTRUMENTS, GENERAL PROCEDURES AND MATERIALS

Equipment, Instruments and General Procedures

Fluorometer-Luminometer

The emission and excitation spectra of the solids were obtained with a Varian Cary Eclipse spectrofluorometer equipped with a microplate reader accessory (Part No. 0010075300, Varian Associates, Walnut Creek CA)). The instrument was operated in time-gated mode. The slits and other settings of the Cary instrument were varied as required. All experiments and measurements were performed at ambient temperature unless stated otherwise.

Microscope

A Leitz MPV II fluorescence microscope equipped with a 10X 0.25 NA, a 40X 0.65 NA, and an infinity corrected objective high ultraviolet transmission UPL Fluorite 60 oil NA 1.25 with aperture (Olympus Part No. 1UB532) objective, was employed to observe and to electronically photograph the cells. UV and blue illumination was provided by either a 100 watt Mercury-Xenon short arc or a Hamamatsu (Bridgewater, NJ) L4634 flashlamp. The UV fluorescence was excited at 365 nm and the emitted light was observed through an Omega Optical (Brattleboro, VT) PloemoPak cube, UV DAPI, equipped with the following: a 365 nm narrow-band-width excitation filter (Omega 365HT25) and a 400 nm Beamsplitter (Omega 400DCLP02). The CCD optical path was optionally equipped with either a 619 nm narrow-

1 band, 5.6 nm width at half maximum, emission filter (Omega 618.6NB5.6) or a standard
2 DAPI 450 nm emission filter (Omega 450DF65). The SFX (fluorescein) stained cells were
3 observed with a standard fluorescein Omega Optical PloemoPak cube (Omega XF100/B/
4 XC120 Vivid). The images were obtained with a peltier cooled, monochrome Quantitative
5 Imaging Corp. (Burnaby, BC, Canada) Retiga-1350 EX, 12 bit ADC, CCD camera (1280 x
6 1024). According to the manufacturer's specification, this camera operates at 25°C below
7 ambient temperature, or ca. 0°C. The gray levels of the images were inverted for display.
8 Darkness indicates strong luminescence.

9 An assembly (Ref. 13) was created to mount the flashlamp to the present Leitz MPV II
10 microscope. The lamp mount is capable of movement in the X,Y, and Z directions. An auxil-
11 iary antireflection coated 100 mm focal length symmetric-convex synthetic fused-silica lens
12 was inserted into the auxiliary filter holder of the epi-illumination system to decrease the opti-
13 cal path between the flashlamp and the rear of the objective.

14 The Retiga-1350 EX was strobed by a special time-delay box, which was provided by
15 Quantitative Imaging Corp. Both the time-delay box and the flashlamp were connected
16 directly to the pulse generator. When operated in preset number of images mode, the Retiga-
17 1350 EX QCapture Software 1394 was set "edge high" (leading edge triggered).

18 When the above mentioned fluorescence microscope is used with the flashlamp, it will be
19 referred to as the flashlamp microscope. The flashlamp microscope can operate in two modes.
20 In one mode, when the flashlamp is continuously fired and the camera is continuously
21 exposed, the results are essentially the same as those obtained with the mercury arc except that
22 the exposures must be longer because of the lower average ultraviolet emission produced by
23 the flash lamp. The second mode is time-gated. In this case, the CCD camera is only exposed
24 subsequent to the ignition of the flashlamp. In this time-gated mode, the delay can be adjusted
25 to eliminate the fluorescence emissions from conventional organic fluorochromes and many
26 cellular components.

27 An Ultraviolet Products (UVP) (Upland, CA) Epi Chem II Darkroom was equipped with a
28 619 nm narrow-band, 5.6 nm half-width, emission filter (Omega 618.6NB5.6) and a special
29 adaptor to mount the Retiga-1350 EX camera.

30

31

1 **Image Manipulation**

2 The TIFF images produced by the Retiga-1350 EX camera were manipulated with
3 Adobe® (San Jose, CA) Photoshop® 7.0. All images were transformed into 8 bit gray and
4 inverted to facilitate visualization. The conversion of a white image on a black background to
5 a black image on a white background produces the equivalent of a conventionally stained
6 absorbance image. The training of practitioners in the field of cytology, such as cytotechnolo-
7 gists and pathologists, is with absorbance images. Other manipulations of 8 or 16 bit images
8 were performed with Fovea (Reindeer Games, Inc. Asheville, NC).

9 MOST COMMONLY USED MATERIALS

10
11 The vendors' addresses are given only in the description of their first product.

12 (a) Tris(hydroxymethyl)aminomethane (TRIS), Ultra Pure Grade (Ameresco, Solon,
13 OH, Catalog No. 0497-1Kg).

14
15 (b) Dimethylsulfoxide (DMSO), ACS Reagent, spectrophotometric grade (Aldrich, St.
16 Louis, MO, Catalog No. 15,493-9 (1996-97)).

17 (c) Triton X-100 (J. T. Baker, Phillipsburg, NJ, Catalog No. X198-07).

18
19 (d) Knox Original Gelatin, Unflavored (Parsippany, NJ).

20 (e) EuMac-di-NCS was prepared according to US Patent 5,696,240, EXAMPLE XXIX
21 B, step 1.

22
23 (f) EuMac-mono-NCS was synthesized according to the procedures of Examples IX and
24 XXXV, Step 1, of US Patent 5,696,240. The material used for the synthesis of the
25 EuMac-mono-NCS from the EuMac-mono-amine included: 34% EuMac-mono-amine,
26 66% unfunctionalized EuMac, and virtually no EuMac-di-amine. Thus, in the final prod-
27 uct the contamination by the cross-linking di-isothiocyanate was minimal. The unfunc-
28 tionalized macrocycle contaminant should only act as a diluting, inert species.

29 (g) 4,4,4-trifluoro-1-(2-thienyl)-1,3-butanedione (Thenoyltrifluoroacetone, HTTFA),
30 99% (Aldrich, Catalog No. T27006). The commercially obtained product was recrystal-
31 lized twice from chloroform/diethylether/hexane using activated charcoal as decolorizing

1 agent, dried in vacuo, and stored at 4°C in a dark glass container.

2
3 (h) 2,6-pyridinedicarboxylic acid, $C_7H_5O_4N$ (H_2PDCA), (Aldrich Chemical Co., St.
4 Louis, MO, Catalog No. P.6, 380-8).

5 (i) High purity Gd(III) trichloride hydrate, $GdCl_3 \cdot n(H_2O)$, was prepared from the oxide,
6 Gd_2O_3 99.999% REO (Alpha Aesar, Ward Hill, MA, Catalog No. 11289 (1999-2000), by
7 dissolving it in 15% aqueous HCl, followed by evaporation to dryness with mild heating
8 under reduced pressure.

9
10 (j) Sodium azide, NaN_3 (Sigma, St. Louis, MO, Catalog No. S-2002).

11
12 (k) Hydroxylamine hydrochloride, $NH_2OH \cdot HCl$, (Sigma Catalog No. H9876).

13 (l) The 1.5 M $NH_2OH \cdot HCl$ (pH8.5) solution is a 1.5 M $NH_2OH \cdot HCl$ aqueous solution
14 that has been adjusted to pH 8.5 with NaOH.

15 (m) 10 x TBS-Azide is a solution (aqueous concentrate) that contains in 1 liter: 100
16 mMols of TRIS, 1.50 Mols of NaCl, and 77.0 mmol of NaN_3 ; the pH is adjusted to 7.4
17 with 12N HCl.

18
19 (n) The TBS-Azide is an aqueous solution which contains in 1 liter: 10 mMols of TRIS,
20 150 mMols of NaCl, and 7.7 mMols of NaN_3 . This solution is prepared by mixing one
21 part 10 x TBS-Azide with 9 parts water and adjusting the pH to 7.4 with 12N HCl and 1N
22 HCl.

23 (o) PEG 1,450, polyethylene glycol with average mol. wt. 1,450 (Sigma, Catalog No. P-
24 5402).

25
26 (p) 5% PEG-EtOH is an ethanolic solution which contains in 1 liter 50 grams of PEG
27 1,450.

28 (q) 4',6-Diamidino-2-phenylindole dihydrochloride, DAPI (Molecular Probes, Eugene,
29 OR, Catalog No. D21490).

30
31 (r) Anti-5-BrdU, a monoclonal antibody specific for 5-BrdU, (Phoenix Flow Systems,

1 San Diego, CA, Catalog No. PRB1U).

2 (s) Streptavidin (Prozyme, San Leandro, CA, Catalog No. SA10).

3 (t) Aminosilane treated slides (Silane-Prep Slides) (Sigma, Catalog No. S4651).

4 (u) 1.5 mL Eppendorf Tubes (Fisher Scientific, Pittsburgh, PA, Catalog No. 22 36 320-
5 4).

6 (v) Clearium Mounting Medium (Surgipath Medical Industries Inc., Richmond, IL, Cat-
7 alog No. 01100).

10 EXAMPLE I

11 Preparation of High Purity Gadolinium Trichloride Hydrate and Yttrium 12 Trichloride Hydrate

13 A. Materials

14 (a) Gadolinium oxide, Gd_2O_3 99.999% (REO) (Alpha Aesar, Word Hill, MA, Catalog
15 No. 11289, 2001-02); and Yttrium oxide, Y_2O_3 99.9999% (REO) (Alpha Aesar, Catalog
16 No. 42864, 2001-02).

17 (b) Hydrochloric acid, HCl, reagent grade, 12 molar (EMD Chemicals Inc., Gibbstown,
18 N.J., Catalog No. HX0603P-1).

19 (c) Chromerge cleaning solution, consisting of chromium oxide, CrO_3 , in concentrated
20 sulfuric acid (Manostat, New York, NY, Catalog No.}).

21 B. Procedure

22 (a) All glassware was cleaned as follows before use: (1) Rinse with methanol/HCl
23 (10%). (2) Rinse with distilled water and dry in oven (60°C). (3) Rinse with Chromerge.
24 (4) Rinse with exchange-column deionized water. (5) Dry in oven (60°C), covered with
25 KimWipe (Kimberly-Clark Corp. Dallas, Texas) tissues to prevent entry of dust particles.

26 (b) The oxide (of gadolinium or yttrium) was dissolved in reagent grade 3 molar aque-
27 ous HCl with mild heating (60°C), and the resulting colorless solution was evaporated to
28

dryness in a rotary evaporator at 60 °C under reduced pressure. The solid residue was further dried for several days in vacuo over phosphorus pentoxide and potassium hydroxide. The product was obtained as a colorless crystalline powder.

EXAMPLE II

Preparation of High Purity Energy Transfer Donor $\text{Gd}(\text{TTFA})_3 \cdot n(\text{H}_2\text{O})$ Complex

A. Materials

- (a) High purity gadolinium trichloride hydrate, $\text{GdCl}_3 \cdot 6(\text{H}_2\text{O})$, prepared as described in EXAMPLE I.
- (b) The HTTFA of the Most Commonly Used Materials.
- (c) 2,2',2''-nitrilotriethanol (Triethanolamine, TEA), 98% (Aldrich, St. Louis, MO, Catalog No. TS,830-0). The product was used as received.
- (d) Solvents: Column-deionized water, methanol, chloroform, hexane (all reagent grade).
- (e) Decolorizing charcoal, Activated Carbon, DARCO G 60 (Aldrich, Catalog No. 24,227-6).

B Procedure

- (a) The gadolinium chloride, obtained as described in EXAMPLE I, was dissolved in methanol at ambient temperature. To the resulting solution, the following were added in sequence, gradually and with stirring: (1) solid HTTFA (1:3 mole ratio), and triethanolamine (TEA) (1:3 mole ratio) previously dissolved in a minimal volume of methanol. After a few minutes, a solid began to precipitate, and the mixture was refrigerated for 12 hours. The colorless crystalline solid that formed was filtered off and shown by its infrared spectrum to be the chloride of the TEA reagent. The filtered solution was diluted to six times its original volume with deionized water and a milky suspension was obtained. The mixture was refrigerated for two days. The powdery solid that formed was filtered with suction and washed by repeatedly flushing with deionized water while still on the

1 filter under suction.

2 (b) The product was purified by repeated fractional crystallization from chloroform/hex-
3 ane, using charcoal as decolorizing agent. It was finally obtained as a cream-colored
4 microcrystalline powder.
5

6 (c) The novel high purity gadolinium complex thus obtained, $\text{Gd}(\text{TTFA})_3 \cdot n(\text{H}_2\text{O})$, was
7 identified by infrared IR spectroscopy. The spectrum was consistent with the formula
8 $\text{Gd}(\text{TTFA})_3 \cdot n(\text{H}_2\text{O})$.

9 (d) The creation of the pure complex eliminated the fluorescent organic impurities origi-
10 nally present in the HTTFA and provided the TTFA ligand as the mononegative anion.
11

12 EXAMPLE III

13 Preparation of High Purity Energy Transfer Donor $\text{Y}(\text{TTFA})_3 \cdot n(\text{H}_2\text{O})$

14 Complex

15 A. Materials

16 (a) High purity yttrium trichloride hydrate, $\text{YCl}_3 \cdot 6(\text{H}_2\text{O})$, prepared as described in
17 EXAMPLE I.
18

19 (b) Materials b through e of EXAMPLE II.
20

21 B. Procedure

22 (a) The procedures of EXAMPLE II are followed with the substitution of yttrium trichlo-
23 ride hydrate, $\text{YCl}_3 \cdot 6(\text{H}_2\text{O})$, for $\text{GdCl}_3 \cdot 6(\text{H}_2\text{O})$.
24

25 (b) The product is purified by repeated fractional crystallization from chloroform/hex-
26 ane, using charcoal as decolorizing agent. It is finally obtained as a cream-colored micro-
27 crystalline powder.

28 (c) The novel high purity yttrium complex thus obtained, $\text{Y}(\text{TTFA})_3 \cdot n(\text{H}_2\text{O})$ is identi-
29 fied by infrared IR spectroscopy. The spectrum is consistent with $\text{Y}(\text{TTFA})_3 \cdot n(\text{H}_2\text{O})$.
30

31 (d) The creation of the pure complex eliminated the fluorescent organic impurities origi-

nally present in the HTTFA and provided the TTFA ligand as the mononegative anion.

EXAMPLE IV

Preparation of the Energy Transfer Donor $\text{Na}_3\text{Gd}(\text{PDCA})_3$

A. Materials

(a) Sodium hydroxide, NaOH, ACS Grade (EM Science, Affiliate of Merck KGaA, Darmstadt, Germany, Catalog No. SX 0590-1).

(b) Gadolinium(III) oxide, Gd_2O_3 , 99.99% (REO), (Alpha Aesar, Word Hill, MA, Catalog No. 11290, 2001-02).

(c) The 2,6-pyridinedicarboxylic acid of the Most Commonly Used Materials.

(d) Indicating Drierite (anhydrous calcium sulfate with blue cobalt chloride as moisture indicator) (W.A. Hammond Drierite Co., Xenia, OH, Catalog No. 23001).

B. Procedure

(a) The gadolinium oxide (0.181 g, 0.500 mmol), 2,6-pyridinedicarboxylic acid (0.501 g, 3.00 mmol) and sodium hydroxide (0.120 g, 3.00 mmol) were added to 100 mL of deionized water. The mixture was heated at reflux for one hr, after which time all solids had dissolved to give a colorless, clear solution. The solution was evaporated to dryness under pumping in a rotary evaporator and the resulting white solid was kept in a vacuum desiccator, over Drierite, for 24 hr. (Yield: 0.598 g.) The infrared spectrum of the dry product confirmed the formula $\text{Na}_3\text{Gd}(\text{PDCA})_3 \cdot n(\text{H}_2\text{O})$, with $n = 3$ (estimated from the intensity of the -OH absorption of water at 3400 cm^{-1}). The related Eu(III) and La(III) salts have previously been described (Ref. 29).

EXAMPLE V

Enhancement of EuMac Luminescence from a Poly-D-Lysine Coated Plate by the Addition of Ethanolic Columinescence solutions

A. Materials.

- 1 (a) The EuMac-di-NCS of the Most Commonly Used Materials.
- 2 (b) The EuMac-di-NCS in DMSO was prepared by dissolving the EuMac-di-NCS in
3 DMSO to produce at 5 mg/mL (5.4 mM) solution.
- 4 (c) The HTTFA of the Most Commonly Used Materials was stored at 4°C in a dark glass
5 container. The stock solution was 1.00×10^{-2} M in ethanol.
- 6 (d) Gd(III) chloride, $\text{GdCl}_3 \cdot 6\text{H}_2\text{O}$ (Alfa Aesar, Word Hill, MA, Catalog No. 11287).
- 7 (e) 1,10-phenanthroline (Sigma-Aldrich, St. Louis, MO, Catalog No.13,137-7).
- 8 (f) Cetyltrimethylammonium bromide (Sigma-Aldrich, Catalog No. 85,582-0).
- 9 (g) Sodium metabisulfite (Spectrum Chemicals & Laboratory Products, Gardena, CA,
10 Catalog No. SO182).
- 11 (h) The aqueous component of the LEL emulsion consisted of 30 mM TRIS, 1 mL/L Tri-
12 ton X-100 of the Most Commonly Used Materials, 150 mM NaCl, 0.10 mM GdCl_3 , 7.69
13 mM NaN_3 , 10 mM sodium metabisulfite ($\text{Na}_2\text{S}_2\text{O}_5$), and 2.5 g/L gelatin of the Most
14 Commonly Used Materials in water.
- 15 (i) The ethanolic component of the LEL emulsion consisted of 10.81 mM HTTFA, 2.08
16 mM 1,10-phenanthroline and 0.19 mM cetyltrimethylammonium bromide in ethanol.
- 17 (j) The LEL emulsion (Ref. 13) was produced by mixing 30 mL of the aqueous compo-
18 nent with 1 mL of the ethanolic component.
- 19 (k) $\text{GdCl}_3 + 3\text{TTFA} \cdot \text{EtOH}$ was an ethanolic solution that contains per liter: 116 μmol
20 GdCl_3 and 348 μmol HTTFA,
- 21 (l) $\text{Gd}(\text{TTFA})_3 \cdot \text{EtOH}$ was an ethanolic solution containing per liter: 300 μmol of the
22 $\text{Gd}(\text{TTFA})_3$ of EXAMPLE II.
- 23 (m) 384-well Microtiter Poly-D-Lysine Plate (Greiner Bio-One, Longwood, FL, Catalog
24 No. 781946).
- 25
26
27
28
29
30
31

1 (n) The TBS-Azide of the Most Commonly Used Materials.

2 (o) The bicarbonate-carbonate buffer (pH 8.7) consisted of a mixture of 9 parts 1 M
3 NaHCO_3 and 1 part 1 M Na_2CO_3 .

4
5 (p) The wash buffer consisted of a mixture of 20 mM NaHCO_3 and 150 mM NaCl (pH
6 ~8.5).

7
8 B. Procedure

9 (a) Each of the wells was washed twice with 100 μL wash buffer and the supernatant was
10 removed by aspiration.

11 (b) Twenty μL of wash buffer was pipetted into each well.

12 (c) Two μL of bicarbonate-carbonate buffer was added to each well.

13 (d) Two μL of the EuMac-di-NCS in DMSO was added and the solution was mixed by
14 lightly tapping against the microtiter plate wall.

15 (e) The microtiter plate was placed on Pipette Aid® pump (Drummond Scientific Co.,
16 Broomall, PA) and firmly attached with Scotch tape to permit agitation.

17 (f) The plate was covered with aluminum foil; the solution in the wells was incubated
18 with agitation for 30 min and then removed.

19 (g) The wells were washed 5 times with 100 μL of TBS-Azide, which was removed by
20 aspiration.

21 (h) 10 μL of each of the solutions shown in Table 1 were delivered into wells a, b, d, e, g,
22 h, j, k, m, and n and their controls of the microtiter plate. Wells c, f, i, and l served as con-
23 trols and did not receive any fluid.

24 (i) The wells were allowed to air dry overnight in the dark. No special steps were taken to
25 minimize the ambient relative humidity.

26 (j) The microtiter plates were inserted into UVP Epi Chem II Darkroom and illuminated
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28
29
30
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with the long UV (ca. 365 nm) bulb. Digital images were acquired with the Retiga-1350 EX camera. The emission intensity of the bottom of each well was measured with Fovea PhotoShop plug-in where "feature region" is available. The integrated optical density (IOD), which is the integral of the linear measurements and thus is a measurement of the total luminescence and autofluorescence emission, was calculated. For each pair of wells, the integrated emission of the control was subtracted from that of the EuMac labelled well.

(k) The wells in the top row of Figure 1 had the EuMac-di-NCS coupled to their poly-D-Lysine. The wells in the bottom row are negative controls, which have not been coupled with EuMac-di-NCS.

Table 1. Solutions Applied to Wells

a & b	Aqueous LEL
d & e	HTTFA in ethanol
g & h	GdCl ₃ +3TTFA-EtOH
j & k	Gd(TTFA) ₃ -EtOH
m & n	GdCl ₃ in ethanol

Only negative control wells (a and b bottom row) had any significant emission. This was probably due to the Eu(III) contaminant present in the GdCl₃. The Gd(TTFA)₃-EtOH negative control wells (j and k bottom row) had a faint spot in the center. The other negative control wells did not luminesce. As described in US Patent 6,340,744 (Ref. 5), the dry, EuMac-containing wells (a and b top row), to which the LEL (cofluorescence) emulsion had been added, luminesced brightly. The EuMac containing wells (d and e top row), to which only HTTFA had been added, luminesced weakly. The EuMac containing wells (g and h top row), to which the GdCl₃+3TTFA-EtOH)-EtOH had been added, luminesced moderately. The EuMac containing wells (j and k top row), to which the Gd(TTFA)₃-EtOH had been added, luminesced brightly. And the EuMac containing wells (m and n top row), to which the GdCl₃ in ethanol had been added, did not luminesce. Unexpectedly, a simple ethanolic solution of Gd(TTFA)₃ can replace the complex micellar solution of US Patent 6,340,744 (Ref. 5). Surprisingly, the use of the Gd(TTFA)₃ complex instead of the same amount of GdCl₃ +3TTFA, increases the luminescence.

EXAMPLE VIEnhancement of EuMac Luminescence from a Poly-D-Lysine Coated
Plate by the Addition of Ethanol-Water Columinescence solutionsA. Materials.

- (a) The EuMac-di-NCS of the Most Commonly Used Materials.
- (b) The LEL emulsion of the Most Commonly Used Materials.
- (c) Gd-TTFA-EtOH is an ethanolic solution that contains: 116 μM GdCl_3 and 348 μM HTTFA.
- (d) The $\text{Gd}(\text{TTFA})_3$ of EXAMPLE II.
- (e) 384-well Microtiter Poly-D-Lysine Plate (Greiner Bio-One, Longwood, FL, Catalog No. 781946).
- (f) The TBS-Azide of the Most Commonly Used Materials.

B. Procedure

- (a) The procedures of EXAMPLE V were repeated with the substitution of $\text{Gd}(\text{TTFA})_3$ in mixtures of ethanol and water for $\text{Gd}(\text{TTFA})_3\text{-EtOH}$. In the Abbreviations shown in Figure 2, the ethanol percentage is given as a numeric prefix to ETOH.
- (b) As shown in Figure 2, negative control wells (-), left column, (E, F, I, J, K, O, and P) had a weak emission at their periphery. Well (L) had a weak emission from its center. The strongest emissions from the EuMac stained wells (+), right column, were from the two aqueous LEL emulsion samples (O and P), three of the $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ (I, J, and K) and one $\text{Gd}(\text{III})\text{-TTFA-50EtOH}$ (F). The Integrated Luminescence (arbitrary units) is the difference between the luminesce of the europium macrocycle stained well and the unstained control well. Both the formation of the $\text{Gd}(\text{TTFA})_3$ complex from the mixture of GdCl_3 and HTTFA, and the drying of the solutions may have been influenced by the solvent composition.

1 Since the formulation of the $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ is relatively simple, the luminescence
2 obtained with it is comparable to that of the aqueous columinescence solutions, and the
3 air drying from these alcoholic solutions decrease the artifacts associated with air drying
4 cells from aqueous solutions, the use of $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ together with air drying will
5 be very useful for cytology, histology and other determinations of analytes. The low cost
6 of ethanol, its availability in cytology and histology laboratories, and its relative lack of
7 toxicity are also incentives for its use.

8 EXAMPLE VII

9 Enhancement of EuMac Luminescence from a Poly-D-Lysine Coated 10 Plate by the Addition of Other Columinescence solutions

11 A. Materials.

- 12 (a) The EuMac-di-NCS of the Most Commonly Used Materials.
- 13 (b) The LEL emulsion of the Most Commonly Used Materials.
- 14 (c) $\text{Gd}(\text{III})\text{-H}_2\text{O}$ is an aqueous solution that contains per liter: 116 μmol GdCl_3 .
- 15 (d) Gd-MeOH is a methanolic solution that contains per liter: 116 μmol GdCl_3 .
- 16 (e) Gd-Isopropanol is an isopropanol solution that contains per liter: 116 μmol GdCl_3 .
- 17 (f) $\text{TTFA-H}_2\text{O}$ is an aqueous solution that contains per liter: 348 μmol HTTFA.
- 18 (g) TTFA-MeOH is a methanolic solution that contains per liter: 348 μmol HTTFA.
- 19 (h) TTFA-Isopropanol is an isopropanol solution that contains per liter: 348 μmol
20 HTTFA.
- 21 (i) $\text{Gd-TTFA-H}_2\text{O}$ is an aqueous solution that contains per liter: 116 μmol GdCl_3 and 348
22 μmol HTTFA.
- 23 (j) Gd-TTFA-MeOH is a methanolic solution that contains per liter: 116 μmol GdCl_3 and
24 348 μmol HTTFA.
- 25 (k) $\text{Gd-TTFA-Isopropanol}$ is an isopropanol solution that contains per liter: 116 μmol

1 GdCl₃ and 348 μmol HTTFA.

2 (l) Gd(TTFA)₃-H₂O is a saturated solution of the Gd(TTFA)₃ of EXAMPLE II in water.

3
4 (m) Gd(TTFA)₃-MeOH is a methanolic solution that contains per liter: 300 μmol of the
5 Gd(TTFA)₃ of EXAMPLE II.

6
7 (n) Gd(TTFA)₃-Isopropanol is an isopropanol solution that contains per liter: 300 μmol
8 of the Gd(TTFA)₃ of EXAMPLE II.

9 (o) 384-well Microtiter Poly-D-Lysine Plate (Greiner Bio-One, Longwood, FL, Catalog
10 No. 781946).

11
12 (p) The TBS-Azide of the Most Commonly Used Materials.

13 **B. Procedure**

14
15 (a) The procedures of EXAMPLE V were repeated with the substitution of Gd(TTFA)₃-
16 MeOH, Gd(TTFA)₃-Isopropanol, and Gd(TTFA)₃-H₂O for Gd(TTFA)₃-EtOH.

17 (b) As shown in Figure 3, the negative control wells (-), left column, (A, E, H, I, K, and
18 L) had a weak emission at their periphery. The column labeled Mean EuMac - Mean Neg.
19 Cntrl contains the mean difference between the luminescence (arbitrary units) of the
20 EuMac-di-NCS coated well and that of the uncoated control well of each row. Although
21 the negative control well (L) had a weak mean emission from its center (33), this was
22 much weaker than that of the EuMac stained well (185), right column. The two strongest
23 corrected mean emissions from the EuMac stained wells were from the aqueous LEL
24 emulsion sample (A) and the Gd(TTFA)₃-MeOH (L), which were respectively 190 and
25 152. The aqueous formulations Gd(III)-TTFA-H₂O (H) and Gd(TTFA)₃-H₂O (K) showed
26 significantly enhanced corrected mean emissions, respectively 91 and 67, versus the cor-
27 rected mean emission, 14.8, of the well with only HTTFA (E).

28 The Gd(TTFA)₃-MeOH sample (L) had a much stronger corrected emission than all of
29 the other samples except for the aqueous LEL emulsion (A).

30 Since the formulation of the Gd(TTFA)₃-EtOH of EXAMPLE VI and the Gd(TTFA)₃-
31

MeOH are very simple compared to that of the LEL emulsion, the alcoholic solutions evaporate much faster, and their storage characteristics are much better, both alcoholic solutions are to be preferred to an aqueous emulsion. These results could be generalized to suggest the investigation of volatile solvents that can dissolve $\text{Gd}(\text{TTFA})_3$ or other ligand salts. For studies where surface tension and rate of evaporation are not considerations, an aqueous solution of $\text{Gd}(\text{TTFA})_3$ might be considered since water is the least expensive of the solvents.

EXAMPLE VIII

Preparation of EuMac-Streptavidin

A. Materials.

- (a) The EuMac-mono-NCS of the Most Commonly Used Materials.
- (b) 1 M NaHCO_3 adjusted to pH 9.0 with 1 M Na_2CO_3 .
- (c) 50 M NaHCO_3 (pH 8.6) made from a 1 M NaHCO_3 solution. No pH adjustment was required.
- (d) Dimethyl Sulfoxide (DMSO), (Sigma, St. Louis, MO, Product No. D-5879).
- (e) 20 mg/mL of EuMac-mono-NCS in DMSO.
- (f) The Streptavidin of the Most Commonly Used Materials.
- (g) 2-(4-hydroxyphenylazo)-benzoic acid (HABA), (Aldrich, St. Louis, MO, Catalog No. 14,803-2)
- (h) The 1.5 M $\text{NH}_2\text{OH}\cdot\text{HCl}$ (pH8.5) of the most commonly used materials.
- (i) G-25 XK16 column (Sephadex G-25 superfine and XK16/20 column, Amersham Pharmacia, Piscataway, NJ, part no. 17-0031-01 and 18-8773-01, respectively).
- (j) Bradford Method, protein assay kit (Amresco, Solon, Ohio, product code: E535).

B. Procedure

1 (a) 12.5 mg of streptavidin was dissolved in 0.625 mL of 50 mM NaHCO₃ (pH 8.6)
2 buffer. A protein concentration of 31.9 mg/mL was determined from the absorbance at
3 280 nm, measured with a Shimadzu UV 2401 PC Model No. 206-82301-92 spectrophoto-
4 tometer. The samples were examined in stoppered 40 µL quartz cuvettes (Starna, 16.40-
5 Q-10).

6 (b) 0.315 mL of a 31.5 mg/mL streptavidin stock solution (10 mgs of streptavidin) was
7 pipetted into a 2 mL plastic tube (Fisher Scientific, Pittsburgh PA, Catalog No. 02-681-
8 343) with cap (Fisher Scientific, Catalog No. 02-681-360), equipped with a micro stirring
9 bar. To this, 0.186 mL of 50 mM HCO₃ was added to make a total volume of 0.5 mL and
10 a final concentration of streptavidin of 20 mg/mL. Stirring was started and was continued
11 during the entire experiment.

12 (c) 50 µL of a saturated HABA solution in 20mM NaHCO₃ was added. (The pH of this
13 HABA solution was approximately 6.9).
14

15 (d) 55 µL of 1 M NaHCO₃, pH 9.0, was added with stirring.
16

17 (e) 150 µL of a 20 mg/mL solution of EuMac-mono-NCS was added. The molar ratios of
18 the streptavidin, HABA, and EuMac-mono-NCS were 1:2.2:19.4, respectively.

19 (f) The solution was incubated with stirring for 60 min at room temperature (~25 °C)
20

21 (g) At the end of the 60 min period, any remaining isothiocyanate was destroyed by the
22 addition of 4 µL of the 1.5 M NH₂OH·HCl (pH8.5) solution.

23 (h) The mixture was incubated, with stirring, for an additional 30 min to complete the
24 quenching reaction. The magnetic stirring bar was then removed and the tube was centri-
25 fugal for 2 min at 17,000 g (Hermle Z 180 Microcentrifuge) to remove any precipitate
26 that may have formed.
27

28 (i) The clear protein solution was transferred to a 1.5 mL Eppendorf Tube of the Most
29 Commonly Used Materials and purified by size-exclusion chromatography on a Sepha-
30 dex G-25 (Amersham Biosciences, Piscataway, NJ, Catalog No. 17-0033-10) in a column
31 16 mm in diameter by 200 mm long, using TBS-Azide as the eluant and a UV detector.

(j) The first 10 mL fraction contained EuMac-Streptavidin. Each fraction was collected into a 15 mL disposable sterile centrifuge conical tube (Fisher Scientific, Catalog No. 05-539-5).

(k) The protein concentration of each sample was determined according to the instructions provided with the Bradford protein assay kit. The yield of protein conjugate was about 46%.

(l) The UV spectra of the conjugate and of streptavidin were obtained in TBS-Azide pH 7.25 buffer.

(m) As is shown in Figure 4, the streptavidin conjugate had a strong absorption at 250-260 nm, and a comparison between the absorbance of the EuMac-streptavidin conjugate and that of the EuMac-mono-NCS confirmed the presence of coupled europium macrocycles. A perfect matching of the spectra would not be expected since the isothiocyanate group of the EuMac-mono-NCS is replaced during coupling by a thiourea group, and the spectrum of the EuMac-mono-NCS was obtained in DMF.

EXAMPLE IX

Linearity Study of EuMac-Streptavidin Binding to Biotinylated Microwells

A. Materials

(a) The EuMac-Streptavidin of EXAMPLE VIII, diluted in the TBS-Azide of the Most Commonly Used Materials to a concentration of 0.23 mg/mL.

(b) The Streptavidin of the Most Commonly Used Materials.

(c) Fluorescein-labeled streptavidin (Phoenix Flow Systems, San Diego, CA, Catalog No. SAFM1.

(d) Reacti-Bind Biotin Coated Microwell Strip Plates (Pierce Biotechnology, Inc., Rockford, IL, Catalog No. 15151).

(e) $\text{Gd}(\text{TtFA})_3\text{-EtOH}$ is an ethanolic solution that contains per liter: 300 μmol of the

1 Gd(TTFA)₃ of EXAMPLE II.

2

3 (f) BSA pH 7.0 is a solution that contains 0.5% w/v BSA in the TBS-Azide of the Most
4 Commonly Used Materials.

5

6 (g) BSA pH 8.5 is a solution that contains 0.5% w/v BSA in the TBS-Azide. The final
7 pH is 8.5.

8

9 (h) Parafilm 4 in. x 125 ft. roll (Laboratory Film), (Pechiney Plastic Packaging, Mena-
sha, WI, Catalog No. PM-996).

10 B Procedure

11

12 (a) One hundred μ L of BSA pH 8.5 was added to each of the Biotin-Coated Microwells
13 and the supernatant was removed by aspiration. A second 100 μ L of BSA pH 8.5 was
14 added. The biotinylated wells were incubated for 15 min at room temperature (26 °C) and
15 the supernatant was removed by aspiration.

16

17 (b) The biotinylated wells were rinsed twice with 100 μ L of BSA pH 7.0.

18

19 (c) A series of dilutions of the EuMac-Streptavidin conjugate were made to create solu-
20 tions with 1,200, 240, 48, 9.6 and 1.92 ng/mL of the conjugate in BSA 7.0. Two control
21 solutions, containing 150,000 ng/mL of either streptavidin or of the fluorescein conjugate
22 of streptavidin in BSA 7.0, were also prepared.

23

24 (d) 100 μ L of each of the EuMac-Streptavidin conjugate samples was added to a biotiny-
25 lated well and the solutions were agitated to facilitate the binding of the streptavidin con-
26 jugates to the biotin by lightly tapping against microtiter strip wall. The microtiter strip
27 was covered with Parafilm to prevent evaporation and incubated at room temperature (26
28 °C) for 40 min in the dark.

29

30 (e) The supernatants were removed and the biotinylated wells were washed 3 times with
31 100 μ L of BSA pH 7.0, which was removed by aspiration.

32

33 (f) The biotinylated wells were allowed to dry.

34

- 1 (g) Two drops (~25 μ L) of the Gd(TTFA)₃-EtOH was added to each biotinylated well.
- 2
- 3 (h) The biotinylated wells were allowed to air dry overnight in the dark.
- 4
- 5 (i) The microwell strip plates were inserted into UVP Epi Chem II Darkroom, illumi-
6 nated with the long UV (ca. 365 nm) bulb, and the emission was passed through a 619
7 nm filter. Digital images of the strip plates were acquired with the Retiga-1350 EX
8 camera.
- 9
- 10 (j) The image of the center 81% of the area of the biotinylated well was analyzed. The
11 mean of the luminescence emission intensity was calculated with Fovea PhotoShop
12 plug-in under Filter/IP*Features/Regions.
- 13
- 14 (k) In the graph of Figure 5, the equation of the linear part of the emission intensity of
15 EuMac-streptavidin bound to the biotinylated wells is $y = 0.0038x + 26.064$ and the lin-
16 earity is $R^2 = 0.9995$. This demonstrates that the EuMac-labeled member of a specific
17 combining pair can be detected and quantitated after being dried from a homogeneous
18 solution. For unknown, possibly instrumental reasons, the first two points have a much
19 steeper slope. The emissions of control samples of streptavidin and of fluorescein-
20 labeled streptavidin, both at 150,000 ng/mL, and of BSA at 5 mg/mL are shown at the
21 ordinate. Although the streptavidin-fluorescein conjugate has saturated the well, only a
22 very small part of the long wavelength tail of the fluorescein emission passes through the
23 619 nm filter. The sensitivity of this assay can be improved by the use of either a time
24 gated system and or an optimized optical system capable of gathering a larger part of the
25 luminescent emissions. Thus, the feasibility of immunoassays and other assays involving
26 specific combining pairs has been demonstrated.
- 27
- 28
- 29
- 30
- 31

EXAMPLE XOptimization of the Lanthanide Enhanced Luminescence of EuMac by
HTTFA and Gd(TTFA)₃A. Materials

(a) The EuMac-Streptavidin of EXAMPLE VIII diluted in the TBS-Azide of the Most Commonly Used Materials to a concentration of 0.05 mg/mL.

(b) Reacti-Bind Biotin Coated Microwell Strip Plates (Pierce Biotechnology, Inc., Rockford, IL, Catalog No. 15151).

(c) The Gd(TTFA)₃ of EXAMPLE II was dissolved in ethanol to produce a 1.0×10^{-2} M, or 1.0×10^7 nM, stock solution. This solution was serially diluted tenfold with ethanol to produce a series of solutions, Gd(TTFA)₃-EtOH solutions, with the most dilute solution being 1.0×10^{-9} M or 1.0 nM. For these solutions, the concentration expressed as Eqv/L of TTFA anion is equal to three times the concentration expressed as molarity of Gd(TTFA)₃ complex. Thus, the Gd(TTFA)₃-EtOH solutions ranged from 3.0×10^7 nEqv/L to 3.0 nEqv/L of TTFA anions.

(d) A 30 mM stock solution of the HTTFA of the Most Commonly Used Materials in ethanol. This solution was serially diluted tenfold with ethanol to produce a series of solutions, HTTFA-EtOH solutions, with the most dilute solution being 3.0×10^{-9} M or 3.0 nM. Each HTTFA-EtOH solution had the same enhancer concentration as its corresponding Gd(TTFA)₃-EtOH solution, except for the enhancer being in the molecular HTTA form instead of the mono-negative anionic TTFA form. For HTTFA, the concentration of material expressed as Eqv/L of the acid is equal to that expressed as molarity.

(e) The BSA pH 7.0 of EXAMPLE IX.

(f) The BSA pH 8.5 of EXAMPLE IX.

(g) The Parafilm of EXAMPLE IX.

B Procedure

1 (a) One hundred μL of BSA pH 8.5 was added to each of the wells of the Reacti-Bind
2 Biotin Coated Microwell Strip Plates at room temperature ($26\text{ }^{\circ}\text{C}$) and the supernatant
3 was removed by aspiration.

4
5 (b) A second 100 μL of BSA pH 8.5 was added to each well. The wells were incubated
6 for 15 min. at room temperature ($26\text{ }^{\circ}\text{C}$) and the supernatant was removed by aspiration.

7 (c) Just prior to use, 0.05 mg/mL EuMac-Streptavidin solution was diluted with the BSA
8 pH 7.0 solution to a final concentration of 0.5 $\mu\text{g/mL}$.

9
10 (d) 50 μL of the 0.5 $\mu\text{g/mL}$ EuMac-Streptavidin solution was pipetted into each of eight
11 biotinylated well. An equal number of control wells did not receive the EuMac-Streptavi-
12 din. Then, the microtiter strip was covered Parafilm to prevent evaporation and incubated
13 at room temperature ($25\text{ }^{\circ}\text{C}$) and in the dark for approximately 30 min.

14 (e) The supernatants were removed and the EuMac-Streptavidin and control wells were
15 washed 3 times with 100 μL of BSA pH 7.0, which was removed by aspiration.

16
17 (f) The wells were allowed to dry at room temperature.

18 (g) The $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ serial dilutions, from $1.0 \times 10^7\text{ nM}$ to 1.0 nM, were added to a
19 set of 8 wells (30 μL per well), in a sequential manner. Both EuMac-Streptavidin-coated
20 wells and control wells were so treated.

21
22 (h) The TTFA-EtOH serial dilutions, from $3.0 \times 10^7\text{ nM}$ to 3.0 nM, were added to
23 another set of 8 wells (30 μL per well), in a sequential manner. Both EuMac-Streptavidin-
24 coated wells and control wells were so treated.

25 (i) The microtiter strips were allowed to air dry overnight in the dark.

26
27 (j) The microtiter strips were placed into UVP Epi Chem II Darkroom and illuminated
28 with the long UV (ca. 365 nm) bulb and the emission passed through a 619 nm filter.
29 Digital images of the strips were acquired with the Retiga-1350 EX camera.

30 (k) The image of the center 81% of the area of the microwell was analyzed. The average
31 emission intensity was calculated with Fovea PhotoShop plug-in under Filter/IP*Fea-

tures/Regions. Four sets of data were measured: Gd(TTFA)₃-EtOH added to control wells (Ctrl. Gd(TTFA)₃), Gd(TTFA)₃-EtOH added to EuMac-Streptavidin coated wells (EuMac-Strept + Gd(TTFA)₃), HTTFA-EtOH added to control wells (Ctrl. HTTFA), and HTTFA-EtOH added to EuMac-Streptavidin coated wells (EuMac-Strept + HTTFA). The data are shown in Table 2. The average emission intensities for the Gd(TTFA)₃ solutions are shown on the left and those for the HTTFA solutions on the right. As expected because of the small europium contamination in the gadolinium, there is an increase in luminescence with concentration for the Gd(TTFA)₃ solutions in the control wells (Ctrl. Gd(TTFA)₃). The results with the HTTFA solutions in the control wells (Ctrl. HTTFA) are essentially constant. The maxima for both solutions occurred at the second highest concentration, 1.0×10^6 nM Gd(TTFA)₃ and 3.0×10^6 nM HTTFA. An inner filter effect is a possible explanation for the quenching of the luminescence at the highest concentration.

Table 2

Gd (TTFA) ₃ (nM)	EuMac-Strept + Gd (TTFA) ₃	Ctrl. Gd (TTFA) ₃	EuMac-Strept + Gd (TTFA) ₃ -Ctrl.	HTTFA (nM)	EuMac-Strept + HTTFA	Ctrl. HTTFA	EuMac-Strept + HTTFA -Ctrl.
1.0×10^7	140	61	80	3.0×10^7	42	22	20
1.0×10^6	160	40	120	3.0×10^6	49	23	26
1.0×10^5	75	37	38	3.0×10^5	46	24	22
1.0×10^4	31	25	5	3.0×10^4	35	23	11
1.0×10^3	25	26	-1	3.0×10^3	31	23	8
1.0×10^2	23	25	-2	3.0×10^2	28	23	5
1.0×10^1	21	21	-1	3.0×10^1	25	22	3
1.0	19	20	0	3.0	22	20	2

(l) Figure 6 consists of plots of the EuMac-Streptavidin net luminescence (Gd(TTFA)₃ - Ctrl. and HTTFA - Ctrl.), corrected for the background from the control wells. Only the concentration in nEqv/L of TTFA anions or HTTFA molecules is shown. In order to pro-

vide the same number of enhancers, the concentrations of the HTTFA solutions are three times those of the $\text{Gd}(\text{TTFA})_3$. The increases in luminescence that resulted from the additions of the $\text{Gd}(\text{TTFA})_3$ (circles) and of the HTTFA (squares) solutions are shown. The ratio (triangles) of these increases is also shown. At low concentrations of $\text{Gd}(\text{TTFA})_3$, the luminescence of the EuMac-Streptavidin was less than that observed with a comparable concentration of HTTFA. This possibly resulted from a significant fraction of the europium macrocycles being incompletely complexed with TTFA because of the competition between the $\text{Gd}(\text{III})$ ions and the EuMacs for the insufficient supply of TTFA ligands. At higher concentrations, the supply of TTFA ligands from the $\text{Gd}(\text{TTFA})_3$ was sufficient to produce cofluorescence, which was maximum for 1.0×10^6 nM $\text{Gd}(\text{TTFA})_3$ with an emission intensity ratio of 4.6 between the sample with added $\text{Gd}(\text{TTFA})_3$ and the sample with the equivalent content of HTTFA.

(m) This experiment was repeated (data not shown) with a different lot of the EuMac-Streptavidin. The maxima for both solutions occurred again with 1.0×10^6 nM $\text{Gd}(\text{TTFA})_3$ and 3.0×10^6 nM HTTFA, and the maximum ratio was again 4.6. For both experiments, removal of the europium contaminant present in the gadolinium used to produce $\text{Gd}(\text{TTFA})_3$ would significantly increase this ratio.

In the solid phase, the ratio (4.6) between the luminescence intensity of samples of EuMac-Streptavidin with $\text{Gd}(\text{III})$ and without $\text{Gd}(\text{III})$, both at the same total content of TTFA, shows that the presence of $\text{Gd}(\text{III})$ produced a useful luminescence enhancement, although smaller than for samples of comparable concentration in the aqueous LEL emulsion. Example VII of US 6,340,744 teaches that the presence of $\text{Gd}(\text{III})$ with a EuMac-avidin conjugate resulted in a "more than ten times higher (luminescence) than that of the other solutions". The simplest explanation for the unexpected decrease in luminescence intensity ratio (from 10 to 4.6) with the system considered in this Example is that the lower ratio is not the result of a diminution of energy transfer from the $\text{Gd}(\text{TTFA})_3$ to the EuMac; but instead, is the result of resonance energy transfer (Ref. 30) by HTTFA molecules or by the excess TTFA anions, which are neither complexed with the gadolinium ion nor bound to Eu macrocycles. This energy transfer either could occur directly to the europium ion, or indirectly by homogeneous resonance energy transfer (Ref. 30) to the TTFA anions that are complexed to the europium.

1 The evaporation of the solvent increases the concentration of the unbound HTTFA molecules
2 and unbound TTFA anions and decreases their distance from the EuMac and its bound TTFA
3 anions, thus favoring the energy transfer process. Thus the HTTFA containing solutions are
4 unitary luminescence enhancing solutions.

5 EXAMPLE XI

6 Optimization of the Lanthanide Enhanced Luminescence of EuMac in 7 the Presence of TTFA Anions

8 A. Materials

- 9
10 (a) The EuMac-Streptavidin of EXAMPLE VIII diluted in the TBS-Azide of the Most
11 Commonly Used Materials to a concentration of 0.05 mg/mL.
12
13 (b) Reacti-Bind Biotin Coated Microwell Strip Plates (Pierce Biotechnology, Inc., Rock-
14 ford, IL, Catalog No. 15151).
15
16 (c) The $\text{Gd}(\text{TTFA})_3$ of EXAMPLE II was dissolved in ethanol to produce a 10,000 μM
17 (10 mM) stock solution. This ethanolic 10 mM stock solution was prepared by dissolving
18 8.2 mg in 1.0 mL of ethanol. This solution was serially diluted tenfold with ethanol to
19 produce 1000 μM , 100 μM , and 10.0 μM $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ solutions.
20
21 (d) NaTTFA was prepared by mixing the HTTFA of the Most Commonly Used Materi-
22 als (1.11 g, 5.00 mmol, dissolved in 5.0 mL of anhydrous ethanol) with NaOH (0.200 g,
23 5.00 mmol, dissolved in 20 mL of anhydrous ethanol). The clear solution thus obtained
24 was evaporated to dryness under reduced pressure. The residue was taken up with 5.00
25 mL of diethylether and 25 mL of hexane were slowly added to the resulting mixture, with
26 stirring. After refrigeration for 12 hr, the white powdery solid that had formed was fil-
27 tered off, washed with hexane, and dried in vacuo over Drierite. The IR spectrum of the
28 product confirmed its composition.
29
30 (e) A 30 mM stock ethanolic solution of the NaTTFA (NaTTFA-EtOH) was prepared by
31 dissolving of (8.6 mg) in 1.174 mL of ethanol. This 30 mM NaTTFA-EtOH solution was
serially diluted tenfold with ethanol to produce 3000 μM , 300 μM , and 30.0 μM NaT-
TFA-EtOH solutions. Each NaTTFA-EtOH solution had the same TTFA anion concentra-

tion as one of the $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ solutions of Step (c).

(f) Equal volumes of the $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ and Na-TTFA-EtOH solutions from (c) and (e), having the same TTFA anion concentrations, were mixed together to produce corresponding Gd+Na(TTFA) solutions with the same series of concentrations.

(g) The BSA pH 7.0 of EXAMPLE IX.

(h) The BSA pH 8.5 of EXAMPLE IX.

(i) The Parafilm of EXAMPLE IX.

B. Procedure

(a) Steps (a) through (f) of the procedures of EXAMPLE X were repeated.

(b) The 1,000 μM , 100 μM , and 10.0 μM $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ solutions were added to a set of 6 wells (30 μL per well), in a sequential manner. Each solution was added to a EuMac-Streptavidin-coated well and control well.

(c) The 3,000 μM , 300 μM , and 30.0 μM NaTTFA-EtOH solutions were added to a set of 6 wells (30 μL per well), in a sequential manner. Each solution was added to a EuMac-Streptavidin-coated well and to a control well.

(d) The 3,000 $\mu\text{Eqv/L}$, 300 $\mu\text{Eqv/L}$, and 30.0 $\mu\text{Eqv/L}$ Gd+Na(TTFA) solutions were added to a set of 6 wells (30 μL per well), in a sequential manner. Each solution was added to a EuMac-Streptavidin-coated well and to a control well.

(e) Steps (i), (j), and (k) of the procedures of EXAMPLE X were repeated.

(f) Six sets of data were measured: $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ added to EuMac-Streptavidin coated wells ($\text{EuMac-Strept} + \text{Gd}(\text{TTFA})_3$), $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ added to control wells (Ctrl. $\text{Gd}(\text{TTFA})_3$), NaTTFA-EtOH added to EuMac-Streptavidin coated wells ($\text{EuMac-Strept} + \text{NaTTFA}$), NaTTFA-EtOH added to control wells (Ctrl. NaTTFA), the Gd+Na(TTFA) solutions added to EuMac-Streptavidin coated wells ($\text{EuMac-Strept} + \text{Gd+Na(TTFA) Solution}$), and the Gd+Na(TTFA) solutions added to control wells (Ctrl.

Gd+Na(TTFA) Solution). The data are shown in Figure 7 and in Table 3. The results for the wells treated with the Gd(TTFA)₃ solutions are shown on the left and those for the wells treated with the Na(TTFA) solutions on the right of Table 3a. As expected because of the small europium contamination in the gadolinium, there is an increase in luminescence with concentration for the Ctrl. Gd(TTFA)₃ wells. The results for the Na(TTFA) in the Ctrl. Na(TTFA) wells are essentially constant. With the EuMac-Streptavidin coated wells, the maximum net luminescence occurred at the highest concentration, 1,000 μM, for the Gd(TTFA)₃ and at the second highest concentration, 300 μM, for the Na(TTFA).

Table 3a

Gd (TTFA) ₃ (μM)	EuMac- Strept + Gd (TTFA) ₃	Ctrl. Gd (TTFA) ₃	EuMac- Strept + Gd (TTFA) ₃ -Ctrl.	Na (TTFA) (μM)	EuMac- Strept + Na (TTFA)	Ctrl. Na (TTFA)	EuMac- Strept + Na (TTFA) -Ctrl.
1,000	136.9	32.2	104.7	3,000	65.9	37.7	28.3
100	100.5	25.3	75.5	300	61.8	24.8	37.1
10	45.6	21.7	24.0	30	52.6	23.0	29.6

Table 3b

Gd (TTFA) ₃ (μM)	Na (TTFA) (μM)	EuMac- Strept + Gd+Na(TTFA) Solution	Ctrl. Gd+Na(TTFA) Solution	EuMac- Strept + Gd+Na(TTFA) Solution -Ctrl.
500	1,500	188.0	34.9	153.1
50	150	100.6	30.7	69.9
5	15	43.7	27.8	16.1

The results for the wells treated with the Gd+Na(TTFA) solutions are shown in Table 3b. As expected because of the small europium contamination in the gadolinium, there is an increase in luminescence with concentration for the control wells. With the EuMac-Streptavi-

1 din coated wells, the maximum net luminescence occurred at the highest concentration, 1,000
2 μM (3,000 $\mu\text{Eqv/L}$), for the $\text{Gd}(\text{TTFA})_3$ and $\text{Gd}+\text{Na}(\text{TTFA})$ solutions; the maximum net
3 luminescence occurred at the second highest concentration, 300 μM , for the NaTTFA solu-
4 tion. For each data point, the concentration of the TTFA anions was 3 times the concentration
5 of the $\text{Gd}(\text{TTFA})_3$, shown on the abscissa of Figure 7. An inner filter effect is a possible expla-
6 nation for the quenching of the luminescence at the highest concentration of $\text{Na}(\text{TTFA})$.

7 In the solid phase, the ratio (3.7) between the luminescence intensity of the EuMac-Strepta-
8 vidin samples with $\text{Gd}(\text{TTFA})_3$ and the EuMac-Streptavidin samples with $\text{Na}(\text{TTFA})$, both at
9 the same total concentration of TTFA anions (3,000 $\mu\text{Eqv/L}$), shows (Table 3a) the enhance-
10 ment caused by gadolinium to be lower than observed in EXAMPLE X, where the ratio was
11 4.6. The ratio was further decreased, to a value of 2.8, when taken at the highest net intensity
12 value for the EuMac-Streptavidin samples with $\text{Na}(\text{TTFA})$, corresponding to a TTFA concen-
13 tration of 300 $\mu\text{Eqv/L}$. At the highest concentrations of the $\text{Gd}(\text{TTFA})_3$ (Table 3a) and
14 $\text{Gd}+\text{Na}(\text{TTFA})$ solutions (Table 3b), the ratio of the luminescence intensities (104.7/153.1)
15 was 0.7. Thus, under some conditions, lowering the concentration of the $\text{Gd}(\text{III})$ ion can
16 increase the luminescence intensity.

17 Example VII of US 6,340,744 teaches that the presence of $\text{Gd}(\text{III})$ with a EuMac-avidin
18 conjugate in a micellar solution resulted in a "more than ten times higher (luminescence) than
19 that of the other solutions". The simplest explanation for the unexpected decrease in lumines-
20 cence intensity ratio (from 10 to 3.7) with the system considered in this Example is that the
21 lower ratio is not the result of a diminution of energy transfer from the $\text{Gd}(\text{TTFA})_3$ to the
22 EuMac; but instead, is the result of resonance energy transfer (Ref. 30) by the excess TTFA
23 anions, which are neither complexed with the gadolinium ion nor bound to Eu macrocycles.
24 This unexpected energy transfer either could occur directly to the europium ion, or indirectly
25 by homogeneous resonance energy transfer (Ref. 30) to the TTFA anions that are complexed
26 to the europium ion. The evaporation of the solvent increases the concentration of the HTTFA
27 molecules and TTFA anions, thus favoring the energy transfer process. Thus the $\text{Na}(\text{TTFA})$
28 and $\text{Gd}(\text{TTFA})_3$ containing solutions and their mixtures are unitary luminescence enhancing
29 solutions.

30 EXAMPLE XII

Optimization of the Lanthanide Enhanced Luminescence of EuMac in
the Presence of TTFA Anions and HTTFA

A. Materials

(a) The materials of EXAMPLE XI.

(b) The 30 mM stock solution of the HTTFA in ethanol (HTTFA-EtOH) of EXAMPLE X was serially diluted tenfold with ethanol to produce 3000 μ M, 300 μ M, and 30.0 μ M HTTFA-EtOH solutions. Each HTTFA-EtOH solution had the same enhancer concentration as its corresponding Gd(TTFA)₃-EtOH solution, except for the enhancer being in the molecular HTTA form instead of the mono-negative anionic TTFA form.

(c) The Gd+HTTFA solutions were prepared by mixing equal volumes of the Gd(TTFA)₃-EtOH and HTTFA-EtOH solutions.

(d) The Na+HTTFA solutions were prepared by mixing equal volumes of the Na(TTFA)-EtOH and HTTFA-EtOH solutions.

B. Procedure

(a) Steps (a) through (f) of the procedures of EXAMPLE X were repeated.

(b) The 10,000 μ M, 1,000 μ M, 100 μ M, and 10.0 μ M Gd(TTFA)₃-EtOH one-component solutions were each added to 3 wells (30 μ L per well). Two aliquots of each solution were added to EuMac-Streptavidin-coated wells and a third to a control well.

(c) The procedure of step (b) was repeated with the HTTFA-EtOH and NaTTFA-EtOH one-component solutions. However, since in Gd(TTFA)₃-EtOH there are 3 TTFA anions for each Gd(III), the concentrations of the 30 μ L aliquots of the HTTFA-EtOH and Na(TTFA)-EtOH solutions were 30,000 μ M, 3,000 μ M, 300 μ M, and 30 μ M, respectively.

(d) Three One-to-One 30,000 μ Eqv/L stock solutions were made by mixing equal volumes of two one-component stock solutions. The Na+HTTFA solution consisted of equal volumes of the NaTTFA-EtOH and the HTTFA-EtOH solutions. The Gd+HTTFA solu-

tion consisted of equal volumes of the $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ and the HTTFA-EtOH solutions. And the $\text{Gd+Na}(\text{TTFA})$ solution consisted of equal volumes of the $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ and the $\text{Na}(\text{TTFA})\text{-EtOH}$ solutions. For each of these One-to-One solutions, the concentrations of the TTFA anion, of the HTTFA molecule, or of their sum were 30,000 $\mu\text{Eqv/L}$, 3,000 $\mu\text{Eqv/L}$, 300 $\mu\text{Eqv/L}$, and 30 $\mu\text{Eqv/L}$.

(e) The three One-to-One solutions were each added to 3 wells (30 μL per well). Two of the three aliquots of each set were added to a EuMac-Streptavidin-coated wells and the third to a control well.

(f) Steps (i), (j), and (k) of the procedures of EXAMPLE X were repeated.

(g) The data points from the two EuMac-Streptavidin-coated wells of each set were averaged and the luminescence from the control well was subtracted. These averaged net results are shown in Table 4 and Figure 8. The results for the wells treated with the One-to-One solutions are shown on the left and those for the wells treated with the one-component solutions are shown on the right of Table 4. The maximum net luminescence occurred at the second highest concentration, 3,000 $\mu\text{Eqv/L}$, for both One-to-One solutions containing Gd(III) , namely the Gd+HTTFA and the $\text{Gd+Na}(\text{TTFA})$ solutions. The difference between these two values (109.0 and 103.3) is within the error of the experiment. Both of these values are greater than the maximum value (62.5) for the one-component $\text{Gd}(\text{TTFA})_3$ solution, which also occurs at 3,000 $\mu\text{Eqv/L}$, and are over 4 times the maximum values for the HTTFA (22.0), NaTTFA (16.0), and the Na+HTTFA One-to-One solution (26.0), which occurred at the highest concentration, 30,000 $\mu\text{Eqv/L}$.

Table 4

	One-to-One Solutions			One-Component Solutions			
TTFA $\mu\text{Eqv/L}$	Na + HTTFA	Gd + HTTFA	Gd + Na (TTFA)	HTTFA	Na (TTFA)	Gd (TTFA) ₃	TTFA nEqv per well
30,000	26.0	38.7	80.0	22.0	16.0	10.6	900

Table 4

3,000	18.3	109.0	103.3	16.0	15.8	62.5	90
300	14.2	32.1	31.8	11.3	11.7	29.6	9.0
30	12.7	12.7	13.3	7.9	8.7	8.8	0.90

(h) As in EXAMPLE X and in EXAMPLE XI, increasing the concentration of the TTFA anions or of the HTTFA molecules results in an increase in luminescence and the addition of Gd(III) can modulate the luminescence, in this case by increasing it. The presence of Gd(III) can also change the concentration of the TTFA anion and/or the HTTFA molecule where maximum luminescence occurs. Unexpectedly, the One-to-One mixtures of Gd(TTFA)₃ with either HTTFA or Na(TTFA) both have increased luminescence compared to the One-Component solutions of Gd(TTFA)₃ and Na(TTFA). Since at these concentrations of Na(TTFA) the ligand binding sites of the EuMac are fully saturated by TTFA ligands, the excess TTFA anions must have been a significant source of the energy emitted by the EuMac. The increase in emission resulting from the presence of the Gd(III) again provides evidence that this ion can modulate the efficiency of energy transfer from the TTFA anion and from the HTTFA molecule. The increased emission from the One-to-One mixture of Gd(TTFA)₃ with Na(TTFA) at the highest concentration demonstrates that changes in the ratio of cations can modulate, in this case increase, the emission from the EuMac. Unexpectedly, as shown in Table 4, the relative net luminescence of the One-Component solutions with molecular HTTFA is approximately equal to that of the NaTTFA. Thus, the excess HTTFA transfers energy by a means other than homogeneous resonance energy transfer to the EuMac. In this regard the HTTFA is behaving like a standard fluorophore or lumiphore or both. This finding opens the possibility of a new means for energy transfer to LnMacs and other energy transfer acceptor lanthanide(III) complexes, utilizing conventional including commercially available, fluorophores or lumiphores as energy transfer donors. Thus the HTTFA, Na(TTFA), and Gd(TTFA)₃ containing solutions and their mixtures are unitary luminescence enhancing solutions.

EXAMPLE XIII

Enhancement of EuMac and TbMac Luminescence by the Addition of Methanolic Solutions Containing Na₂PDCA or Na₃Gd(PDCA)₃

1 A. Materials

2 (a) Sodium hydroxide, NaOH, ACS Grade (EM Science, Affiliate of Merck KGaA,
3 Darmstad, Germany, Catalog No. SX 0590-1).

4
5 (b) The 2,6-pyridinedicarboxylic acid, H₂PDCA, of the Most Commonly Used Materi-
6 als.

7
8 (c) Na₂PCDA-MeOH(10⁻³) is a 5.0 x 10⁻³ M solution of Na₂PCDA in methanol. This
9 solution was prepared as follows. The H₂PDCA (167.7 mg, 1.00 mmol) was dissolved in
10 25.0 mL of methanol to give a 4.03 x 10⁻² M solution. The NaOH (167.9 mg, 4.20 mmol)
11 was dissolved in 100.0 mL of methanol to give a 4.20 x 10⁻² M solution. Then 1.25 mL of
12 the H₂PDCA solution and 2.50 mL of the NaOH solution were mixed and the volume was
13 brought up to 10.0 mL with methanol; 5.00 mL of the resulting solution were finally
14 diluted to a total volume of 10.00 mL with methanol.

15 (d) Na₂PCDA-MeOH(10⁻⁴) is a 5.0 x 10⁻⁴ M solution of Na₂PCDA in methanol. This
16 was prepared by diluting 1.00 mL of the Na₂PCDA-MeOH(10⁻³) solution to a total vol-
17 ume of 10.0 mL with methanol.

18
19 (e) The Na₃Gd(PCDA)₃ of EXAMPLE IV.

20 (f) The EuMac-MeOH is a 10.5 μM solution of EuMac-un in methanol.

21
22 (g) The TbMac-MeOH is a 10.8 μM solution of TbMac-un in methanol.

23
24 (h) The Na₃Gd(PCDA)₃-MeOH(10⁻³) is a 3.48 x 10⁻³ M solution of Na₃Gd(PCDA)₃ in
25 methanol, equivalent to 1.04 x 10⁻² Eqv/L solution of the PDCA anions.

26 (i) The Na₃Gd(PCDA)₃-MeOH(10⁻⁴) is a 3.48 x 10⁻⁴ M solution of Na₃Gd(PCDA)₃ in
27 methanol, equivalent to 1.04 x 10⁻³ Eqv/L solution of the PDCA anions.

28
29 (j) White, "U" bottomed, 96 well, microtiter plates (Thermo Electron Corp. (Franklin,
30 MA, part no. 7105).

31

1 (k) Culture tubes, disposable, 13x100 mm (VWR Scientific Products International, West
2 Chester, PA 19380, Catalog No. 60825-414).

3 B. Procedure
4

5 For these studies, the EuMac-MeOH solution and TbMac-MeOH solution were employed
6 in exactly the same manner. Hence the general term LnMac-MeOH will be employed in some
7 of the following when describing steps in procedure that are identical and are performed sepa-
8 rately with each LnMac-MeOH solution.

9 (a) 1 mL of the EuMac-MeOH solution was added to each of six test tubes (Eu set) and 1
10 mL of the TbMac-MeOH solution was added to each of six test tubes of another set (Tb
11 set). The test tubes in each set were labeled 1-6 for identification. No Na₂PCDA-MeOH
12 was added to Test tubes 1, which served as control. The following volumes of the
13 Na₂PCDA-MeOH(10⁻⁴) solution: 100 µL, 200 µL, and 1,000 µL, were added, respec-
14 tively, to test tubes 2, 3, and 4 of both the Eu and the Tb set. The following volumes of the
15 Na₂PCDA-MeOH(10⁻³) solution: 200 µL and 300 µL, were added, respectively, to test
16 tubes 5 and 6 of both the Eu and the Tb set. The solution in each test tube was brought up
17 to a total volume of 2 mL with methanol, to produce two sets of six solutions each having
18 essentially the same concentration of EuMac-un (5.05 µM) or TbMac-un (5.15 µM) and
19 increasing concentrations of Na₂PCDA (0.00 µM, 25.0 µM, 50.0 µM, 251 µM, 501 µM,
20 and 752 µM). For Na₂PCDA, the concentration of material expressed as Eqv/L of anion
21 is equal to that expressed as molarity.

22
23 (b) Seven 250 mL aliquots were taken from each of the twelve Ln-Mac-Na₂PCDA-
24 MeOH solutions of step (a) and added to individual wells of the U bottom plates. This
25 resulted in an array of six sets each for EuMac-Na₂PCDA and TbMac-Na₂PCDA, each
26 consisting of seven wells. All wells contained the same quantity of EuMac-un (1.26
27 nmol) or TbMac-un (1.29 nmol), but the quantity of Na₂PCDA increased in the order 0.0
28 nmol, 6.3 nmol, 12.5 nmol, 62.6 nmol, 125 nmol, and 188 nmol. For Na₂PCDA, the
29 quantity of material expressed as Eqvs of anion is equal to that expressed as moles of
30 Na₂PCDA. The solutions were allowed to dry by storing the plates at room temperature,
31 in the dark, for 24 hr.

(c) 1 mL of the EuMac-MeOH solution was added to each of six test tubes (Eu set) and 1 mL of the TbMac-MeOH solution was added to each of six test tubes of another set (Tb set). The test tubes in each set were labeled 1-6 for identification. No $\text{Na}_3\text{Gd}(\text{PCDA})_3$ was added to Test tubes 1, which served as control. The following volumes of the $\text{Na}_3\text{Gd}(\text{PCDA})_3(10^{-4})$ solution: 200 μL and 1000 μL , were added, respectively, to test tubes 2 and 3 of both the Eu and the Tb set. The following volumes of the $\text{Na}_3\text{Gd}(\text{PCDA})_3(10^{-3})$ solution: 200 μL , 300 μL , and 400 μL , were added, respectively, to test tubes 4, 5 and 6 of both the Eu and the Tb set. The solution in each test tube was brought up to a total volume of 2 mL with methanol, to produce two sets of six solutions each having essentially the same concentration of EuMac-un (5.05 μM) or TbMac-un (5.15 μM) and increasing concentrations of the PCDA anion (0.0 $\mu\text{Eqv/L}$, 104 $\mu\text{Eqv/L}$, 520 $\mu\text{Eqv/L}$, 1,040 $\mu\text{Eqv/L}$, 1,560 $\mu\text{Eqv/L}$, and 2,080 $\mu\text{Eqv/L}$). For these solutions, the concentration expressed as Eqv/L of PDCA anion is equal to three times the concentration expressed as molarity of $\text{Na}_3\text{Gd}(\text{PCDA})_3$ complex.

(d) Seven 250 μL aliquots were taken from each of the twelve five LnMac- $\text{Na}_3\text{Gd}(\text{PCDA})_3$ solutions of step (c) and added to individual wells of the U bottom plates. This resulted in two arrays of six sets, each consisting of seven wells. All wells contained essentially the same quantity of EuMac-un (1.26 nmol) or TbMac-un (1.29 nmol), but the quantity of but the quantity of PDCA ligand, as part of the $\text{Na}_3\text{Gd}(\text{PCDA})_3$ complex increased in the order 0.00 nEqv, 26 nEqv, 130 nEqv, 260 nEqv, 390 nEqv, and 520 nEqv. The solutions were allowed to dry by storing the plates at room temperature, in the dark, for 24 hr.

(e) The dry plates were mounted on the Cary Eclipse microplate reader and scanned. The luminescence emission spectra of the solid residues were obtained with a Varian Cary fluorometer operated in time-gated luminescence mode with a delay of 100 μsec . Fifty emission spectra were summed to produce the final spectrum. The excitation and emission slits were respectively 10 and 2.5 nm.

(f) Four sets of data were measured: EuMac-un with $\text{Na}_2(\text{PDCA})$ and with $\text{Na}_3\text{Gd}(\text{PDCA})_3$, and TbMac-un with $\text{Na}_2(\text{PDCA})$ and with $\text{Na}_3\text{Gd}(\text{PDCA})_3$.

(g) The emission intensity data from the aliquots of the methanolic solutions of each test tube were averaged. In Figure 9a and Figure 9b, the data for the EuMac-un has been reported as the average of the values between 612-621 nm and the data for the TbMac-un has been reported as the average of the values between 540-550 nm.

(h) The abscissa of Figure 9a is the ratio between the equivalents of PDCA anions ($3 \times$ the molarity of the $\text{Na}_3\text{Gd}(\text{PDCA})_3$) and the moles of the lanthanide macrocycles. Unexpectedly, the presence of excess of the PDCA anion significantly increases the luminescence after both the EuMac-un and the TbMac-un (Figure 9a) were already saturated by PDCA. The simplest possible explanation is that the excess PDCA anions, while not bound to the LnMac-un, can excite the LnMac-bound PDCA anions by homogeneous resonance energy transfer. Another possible explanation is that the unbound PDCA anions can transfer energy directly to the lanthanide ions of the LnMac-un complexes.

(i) The abscissa of Figure 9b is the ratio between the equivalents of PDCA anions ($3 \times$ the molarity of the $\text{Na}_3\text{Gd}(\text{PDCA})_3$) and the moles of the lanthanide macrocycles. The ordinates (Relative Luminescence) of Figures 9a and 9b are in the same units. As shown in Figure 9b, the presence of excess of the PDCA anions from the $\text{Na}_3\text{Gd}(\text{PDCA})_3$ significantly increases the luminescence of the EuMac-un (circles) and the TbMac-un (squares), after both are already saturated by PDCA. This demonstrates that the excess PDCA anions in the presence of Gd(III), while not bound to the LnMac-un, can excite the LnMac-bound PDCA anions by homogeneous resonance energy transfer and/or the unbound PDCA anions can transfer energy directly to the lanthanide ions of the LnMac-un complexes.

(j) Each pair of points from the EuMac-un and the TbMac-un in the graphs of the luminescence increase resulting from the additions of the $\text{Na}_2(\text{PDCA})$ solution (Figure 9a) and of the luminescence increase resulting from the additions of the $\text{Na}_3\text{Gd}(\text{PDCA})_3$ solution (Figure 9b) solutions shows the luminescence for samples having the same ratios of Eqv/L of PDCA anions to moles of LnMac. As opposed to the results obtained in the studies with TTFA described in Table 3a of EXAMPLE XI, the inclusion of Gd(III) decreases the luminescence enhancing effect of the PCDA anions for the EuMac-un. However, the inclusion of Gd(III) increases the luminescence of the TbMac-un while

1 increasing the concentration of the anion required to maximize luminescence. Thus, in
2 samples containing PDCA the replacement of the sodium cation by the gadolinium cation
3 can selectively modulate the relative luminescence of lanthanide macrocycles. This effect
4 may be related to the lanthanide ion, (Gd(III)), modulating the energy or other property of
5 electronic levels in the excited PDCA anion prior to the transfer of energy to the acceptor.

6 (k) The presence of Gd(III) resulted in an unexpected decrease of the luminescence of
7 the EuMac and only in a small increase of the luminescence of the TbMac. This finding
8 that excess ligand anions, in the absence of a second Ln(III) as energy transfer donor, can
9 increase the luminescence of the energy transfer acceptor LnMac, has great utility in that
10 it provides a new means to increase the luminescence of the bound LnMac labels without
11 the increase in background brought about by the presence of the energy transfer donor
12 lanthanide or other metal ion, particularly any Ln(III) contaminant. Thus the $\text{Na}_2(\text{PDCA})$
13 and $\text{Na}_3\text{Gd}(\text{PDCA})_3$ containing solutions are unitary luminescence enhancing solutions.

14 EXAMPLE XIV

15 Procedures for the Simultaneous Use of two Lanthanide Labels

16 A. Materials

- 17 (a) The $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ of EXAMPLE V.
18
19 (b) The $\text{Na}(\text{TTFA})\text{-EtOH}$ of EXAMPLE XI.
20
21 (c) The $\text{Na}_2\text{PCDA-MeOH}$ of EXAMPLE XIII.
22
23 (d) The $\text{Na}_3\text{Gd}(\text{PDCA})_3\text{-MeOH}$ of EXAMPLE XIII.
24
25 (e) The $\text{Na}_2(\text{PDCA})\text{-MeOH}$ of EXAMPLE XIII.

26 B. Procedure

- 27 (a) For new types of preparations that are labeled with two or more LnMacs, the receiv-
28 ing surface member is covered with an amount, determined by experimentation, of a uni-
29 tary luminescence enhancing solution which is then allowed to air dry. For instance, if the
30 labels are the EuMac and the SmMac, the unitary solution contains either the
31

1 Gd(TTFA)₃-EtOH or the Na(TTFA)-EtOH, or a mixture of the two. If the labels are the
2 EuMac and the TbMac, the unitary solution contains either the Na₃Gd(PDCA)₃-MeOH or
3 the Na₂(PDCA)-MeOH, or a mixture of the two. For each of the unitary solutions, the
4 relationship between concentration and maximum net luminescence of the LnMac label is
5 determined following the procedures of EXAMPLE XI, with the following substitution: a
6 receiving surface member where a Ln-labeled-material is bound to one or more specific,
7 relocatable positions is used instead of the wells of the Microwell Strip Plates with bound
8 EuMac-streptavidin.

9 EXAMPLE XV

10 Microscopic Visualization of LnMac Stained Cells and/or Other 11 Materials with Excitation by Light with Emissions Below 330 nm

12 A. Procedure

13 (a) Other luminescent lanthanide ions, such as terbium(III), can be visualized with a flu-
14 orescence microscope, provided that they are dried from the appropriate unitary lumines-
15 cence enhancing solution. In the case of terbium(III), unitary solutions such as those
16 described in EXAMPLE XIII are employed. Since the conditions of EXAMPLE XIII
17 included excitation at 280 nm, the fluorescence microscope is modified so that all ele-
18 ments that transmit excitation light are fabricated from fused silica or materials with sim-
19 ilar optical transmission. A light source that emits at 280 nm is employed. A 280 nm
20 excitation filter and a dichroic mirror efficiently reflects 280 nm light and transmits light
21 above 400 nm are used. The emission filter for Tb(III) is centered at 545 nm with a band-
22 width of ± 10 nm.
23

24 EXAMPLE XVI

25 Preparation of the EuMac-Anti-5-BrdU

26 A. Materials

- 27 (a) The bicarbonate-carbonate buffer of the Most Commonly Used Materials.
28
29 (b) The TBS-Azide of the Most Commonly Used Materials.
30
31

(c) Dimethylformamide, DMF, Spectrophotometric Grade (Alfa Aesar, Ward Hill, MA, Catalog No. 13808).

(d) EuMac-mono-NCS of the Most Commonly Used Materials, as solution in DMF (10.8 mg/mL).

(e) The 1.5 M $\text{NH}_2\text{OH}\cdot\text{HCl}$ (pH8.5) solution of the most commonly used materials.

(f) 5-bromo-uridine (5-BrdU), (Sigma, St. Louis, MO, Catalog No. 5002), diluted to 3mg/mL in H_2O .

(g) Coupling solution is an aqueous solution containing: 11.3 mg/mL of the anti-5-BrdU of the Most Commonly Used Materials, 150 mM NaCl, 20 mM NaHCO_3 , and 0.05% NaN_3 (pH 8.5).

(h) The 50 mM NaHCO_3 (pH 8.6) of EXAMPLE VIII.

B. Procedure

(a) The conjugation of the EuMac-mono-NCS followed the description given in Ref. 31.

(b) 442.48 μL of the coupling solution was mixed with 44.25 μL of the 50 mM NaHCO_3 (pH 8.6) in a 2 mL plastic tube with cap, and equipped with a magnetic micro-stir bar. A ten molar excess of 5-BrdU (35.9 μL at 3 mg/mL) was added to the plastic vial to protect the combining site of the anti-5-BrdU. The EuMac-mono-NCS in DMF (130.66 μL of a 10.8 mg/mL solution) was then added to give a nominal (50:1) lumiphore-to-protein ratio. The solution was incubated for 60 min at room temperature, ca. 27 °C.

(c) After 60 min., any remaining isothiocyanate was destroyed by the addition of 1.11 μL of the 1.5 M $\text{NH}_2\text{OH}\cdot\text{HCl}$ (pH8.5) solution (pH 8.5), corresponding to a 1:1 molar ratio to the original EuMac-mono-NCS.

(d) After an additional 30 min to complete the quenching reaction, the solution was transferred to a 1.5 mL centrifuge tube. The reaction vial was rinsed with 10 μL of TBS-Azide, and the rinse was added to the centrifuge tube. This was followed by centrifugation for 2 min at 17,000 (Hermle Z 180 M microcentrifuge) to remove any precipitate that

1 may have formed during the conjugation.

2 (e) The clear solution was transferred to another vial and purified by size-exclusion chro-
3 matography on Sephadex G-25 in an XK16 column (Amersham Biosciences), using
4 TBS-Azide as the eluent and a UV detector. The solvent front (~11 mL) containing the
5 first absorption peak was collected in TBS-Azide and concentrated using a 10,000 molec-
6 ular weight cut off filter (Millipore, Catalog No. PBGC02510) with a 3 mL stir cell (Mil-
7 lipore model 8003, Catalog No. 5125) under inert gas pressure. Helium was used in this
8 experiment.

9 (f) The UV spectra of the conjugate and of anti-5-BrdU were obtained in TBS-Azide pH
10 7.25 buffer.

11 (g) As shown in Figure 10, the EuMac-anti-5-BrdU conjugate had a strong absorption at
12 250-260 nm, and a comparison between the absorbance of the conjugate and that of the
13 EuMac-mono-NCS confirmed the presence of coupled europium macrocycles. A perfect
14 matching of the spectra would not be expected since the isothiocyanate group of the
15 EuMac-mono-NCS is replaced during coupling by a thiourea group, and the spectrum of
16 the EuMac-mono-NCS was obtained in DMF.

17 EXAMPLE XVII

18 Preparation of the SmMac-Anti-5-BrdU and Other LnMac-Anti-5-BrdU

19 A. Materials

20 (a) The SmMac-mono-amine is synthesized according to the procedures of Example VIII
21 of patent 5,696,240, with the substitution of samarium acetate for lanthanum acetate. The
22 SmMac-mono-amine is converted to the SmMac-mono-NCS according to the procedures
23 of Example XXXVI B, Step 1, of US Patent 5,696,240. The SmMac-mono-amine prepa-
24 ration used to synthesize the isothiocyanate includes: 34% SmMac-mono-amine, 66%
25 unfunctionalized SmMac and virtually no SmMac-di-amine. Thus, the contamination of
26 the cross-linking di-isothiocyanate is minimal. The unfunctionalized macrocycle contam-
27 inant should only act as a diluting, inert species.

28 B. Procedure

(a) The procedures of EXAMPLE XVI are followed with the substitution of the SmMac-mono-NCS or other LnMac-NCS for the EuMac-mono-NCS.

(b) The relative absorbance of the SmMac-anti-5-BrdU or other LnMac conjugate shows a contribution of the SmMac spectrum, in that it is higher than the absorbance of the anti-5-BrdU in the regions between 240 to 270 nm and beyond 290 nm. This shows the presence of SmMac-mono-NCS or other LnMac-mono-NCS coupled to the anti-5-BrdU.

EXAMPLE XVIII

Preparation of the TbMac-Anti-5-BrdU

A. Materials

(a) The TbMac-mono-amine is synthesized according to the procedures of Example VIII of Patent 5,696,240, with the substitution of terbium acetate for lanthanum acetate. The TbMac-mono-amine is converted to the TbMac-mono-NCS according to the procedures of Patent 5,696,240, EXAMPLE XXXVI B, Step 1. The TbMac-mono-amine preparation that is used to synthesize the isothiocyanate used for these studies includes: 34% TbMac-monoamine, 66% unfunctionalized TbMac and virtually no TbMac-di-amine. Thus, the contamination of the cross-linking di-isothiocyanate is minimal. The unfunctionalized macrocycle contaminant should only act as a diluting, inert species.

B. Procedure

(a) The procedures of EXAMPLE XVI are followed with the substitution of the TbMac-mono-NCS for the EuMac-mono-NCS.

(b) The relative absorbance of the TbMac-anti-5-BrdU conjugate shows a contribution of the TbMac spectrum, in that it is higher than the absorbance of the anti-5-BrdU in the regions between 240 to 270 nm and beyond 290 nm. This shows the presence of TbMac-mono-NCS coupled to the anti-5-BrdU.

EXAMPLE XIX

Luminescence Studies of EuMac-di-NCS Stained Cells Dried from a Gadolinium(TTFA)₃ Solution

1 A. Materials.

2 (a) The EuMac-di-NCS of the Most Commonly Used Materials.

3
4 (b) A 134 μ M solution of the Gd(TTFA)₃ of EXAMPLE II in ethanol, Gd(TTFA)₃-
5 EtOH.

6 (c) The TBS-Azide of the Most Commonly Used Materials.

7
8 (d) The 1.5 M NH₂OH·HCl (pH8.5) solution of the Most Commonly Used Materials.

9
10 (e) HL60 (non-apoptotic) cells (Phoenix Flow Systems, San Diego, CA, APO-BRDUTM
11 Kit, Catalog No. CC1001).

12 (f) The Gd Rinse Buffer was based on the Phoenix Flow Systems rinse buffer (Ref. 32).
13 The Gd Rinse Buffer consisted of: 10 mM TRIS, 150 mM NaCl, 0.1 mM GdCl₃, 0.25%
14 (w/v) gelatin of the Most Commonly Used Materials, 7.7 mM NaN₃ and 0.1% v/v Triton
15 X-100 of the Most Commonly Used Materials. After all components had been mixed, the
16 pH was adjusted to 7.4 with HCl.

17 (g) The 5% PEG-EtOH solution of the Most Commonly Used Materials.

18
19 (h) Aminosilane treated slides of the Most Commonly Used Materials.

20
21 (i) Clearium Mounting Medium of the Most Commonly Used Materials.

22 (j) Bicarbonate buffer was an aqueous solution containing 150 mM NaCl and 20 mM
23 NaHCO₃ (pH 8.6).

24
25 B. Procedure

26 (a) 1 mL of HL60 (non-apoptotic) cell suspensions (approximately 1×10^6 cells per 1
27 mL) was transferred to a 1.5 mL Eppendorf Tube of the Most Commonly Used Materials.
28 The cell suspensions were centrifuged at 300 g for 5 min and the 70% (v/v) ethanol super-
29 natant was removed by aspiration.

30 (b) The cell pellet was washed with 0.5 mL of TBS-Azide, centrifuged, and aspirated as
31

1 before.

2 (c) The cell pellet was washed with 0.5 mL of bicarbonate buffer, centrifuged, and aspi-
3 rated as before.

4 (d) The cell pellet was resuspended with 100 μ L of the same buffer by pipetting up and
5 down with a 200 μ L pipette tip.

6 (e) 10 μ L of 1 M NaHCO_3 pH ~8.1 was added.

7 (f) 10 μ L of EuMac-di-NCS in DMSO (3-5 mg/mL) was added and mixed by pipetting.

8 (g) The EuMac-di-NCS coupling solution was incubated at room temperature for 30 min
9 in the dark.

10 (h) 5 μ L of The 1.5 M $\text{NH}_2\text{OH}\cdot\text{HCl}$ (pH8.5) solution was added and the solution was
11 mixed by pipetting.

12 (i) The reaction was quenched by incubating at room temperature for an additional 15-20
13 min.

14 (j) The cells were washed three times by addition 0.5 mL TBS-Azide, followed by cen-
15 trifugation, and subsequent aspiration of supernatant.

16 (k) A pair of Leif Centrifugal Cytology Buckets (Ref. 33) (Newport Instruments) that fit
17 a Beckman Coulter (Brea, CA) model GPR centrifuge, each of which holds 2 inserts,
18 were assembled with aminosilane treated slides. Four chamber inserts were used.

19 (l) The cells were resuspended with 0.5 mL of Gd Rinse Buffer, or with the volume of
20 buffer required to obtain the desired cell density for centrifugal cytology with the four
21 chamber Leif Buckets.

22 (m) The cells were centrifuged at 300 g for 5 min in Leif Buckets and the supernatant
23 was removed by aspiration.

24 (n) 100 μ L of 5% PEG-EtOH solution was added to the fixative inlet of the centrifugal
25 cytology sample chambers and sedimented onto the slide-attached cells by accelerating
26

1 the centrifuge for approximately 30 sec. The supernatant was then removed by aspiration.

2 (o) The slides were removed from the Leif Buckets and rinsed twice with ethanol, each
3 time tapping the slides on a paper towel to remove excess liquid. The slides were finally
4 air dried.

5
6 (p) The cell monolayer was flooded with 2 drops of 134 μM $\text{Gd}(\text{TTFA})_3$ in ethanol and
7 air dried.

8 (q) The slide-bound cells were rinsed twice with ethanol, removing excess liquid each
9 time, and then were allowed to air dry.

10
11 (r) 30 μL of Clearium Mounting Medium was pipetted onto the cell area, making sure
12 that all cells were covered.

13 (s) The solvent was evaporated from the Clearium by mild heat generated with a heat
14 gun.

15
16 (t) The cells were observed with a fluorescent microscope, under 365 nm excitation pro-
17 vided by a Hamamatsu L4634 flashlamp placed in a special housing (Ref. 13). The light
18 passed through a UV DAPI cube, which did not include an emission filter. A removable,
19 narrow band-pass 619 nm emission filter was located above the cube.

20 Figure 11 shows two inverted images of the same field of EuMac-di-NCS stained cells that
21 had been prepared by centrifugal cytology, treated with $\text{Gd}(\text{TTFA})_3\text{-EtOH}$, and mounted and
22 dried in Clearium. A 60x oil objective, NA 1.25, was used and the images were binned to 680
23 x 518 pixels. The flash lamp was used as the light source. Figure 11A is an image of a single 5
24 seconds exposure of the CCD camera with the flash lamp operated at 50 Hz with a UV DAPI
25 cube and 619 nm emission filter. Figure 11B is the sum of one thousand 2 msec exposures of
26 the CCD camera with the flash lamp operated at 8 Hz, a time delay of 29 μsec , and only a UV
27 DAPI cube. A time delay system and software supplied by the manufacturer permitted the
28 averaging of one thousand 2 msec exposures. According to the manufacturer, the Retiga-1350
29 EX has an approximately 9 μsec delay before opening its shutter. The total delay, 29 μsec , is
30 the sum of camera delay and the 20 μsec delay produced by the special time-delay box. Simi-
31 lar time delay studies (Ref. 13) with cells stained with the fluorescein derivative, 6-(fluores-

1 cein-5-(and-6)-carboxamido) hexanoic acid succinimidyl ester (SFX mixed isomer), obtained
2 from Molecular Probes (Eugene, OR, Catalog No. F-6129) have shown that this conventional
3 organic fluorophore does not produce any detectable emission after this time-delay (data not
4 shown). Thus, the use of a unitary luminescence enhancing solution for time-gated studies has
5 been demonstrated.

6 EXAMPLE XX

8 EuMac-di-NCS and DAPI Stained Cells

9 A. Materials.

10 (a) 4',6-Diamidino-2-phenylindole dihydrochloride, DAPI (Molecular Probes, Eugene,
11 OR, Catalog No. D-1306).

12 (b) 10 μ M DAPI solution in TBS-Azide, pH 7.4.

13 (c) All other materials are the same as those listed in EXAMPLE XIX

16 B. Procedure

17 (a) The procedures of EXAMPLE XIX were followed and the cells were stained and
18 mounted. The mounting medium was removed with toluene and the slide was rinsed
19 twice with ethanol and allowed to dry.

20 (b) The cells were rehydrated by incubating under TBS-Azide for 5 min in a conical,
21 graduated 50 mL tube (Fisher Scientific, part No, 05-539-6), making sure that the buffer
22 covered the cells.

23 (c) The excess liquid was removed with Kimwipes and the cells were incubated with 50
24 μ L of the 10 μ M DAPI solution for 5 min.

25 (d) The DAPI stained cells were rinsed with TBS-Azide three times.

26 (e) The cells were rinsed twice with 50 μ L ethanol and then air dried.

27 (f) Two drops of Gd(TTFA)₃ in ethanol (134 μ M) were applied and allowed to dry.

28 (g) The cells were then rinsed twice with ethanol and air dried.

1 (h) The cells were covered with Clearium Mounting Medium and heat dried with mild
2 heat from heat gun.

3 Figure 12 shows four inverted images of the same field of cells stained sequentially with
4 the EuMac-di-NCS and DAPI. The cells were prepared by centrifugal cytology, treated with
5 $\text{Gd}(\text{TTFA})_3\text{-EtOH}$, and mounted and dried in Clearium. A 60x oil objective, NA 1.25, was
6 used and the cells were binned to 680 x 518 pixels. The excitation light was provided by the
7 flashlamp and the special lamp housing (Ref. 13). Conventional images were obtained by
8 opening the camera for a fixed time without time-gating.

9 Images A and B were obtained without the use of the time delay. Image A was obtained
10 with the UV DAPI cube and the 619 nm narrow-band emission filter. The flashlamp was oper-
11 ated at 50 Hz and the time exposure was 40 sec. In this image, each cell is entirely stained by
12 the EuMac-di-NCS. Image B was obtained with the UV DAPI cube and the DAPI 450 nm
13 emission filter. The flashlamp was operated at 50 Hz and the exposure was for 8 sec. In this
14 image, only the nucleus of the cell is stained by DAPI, which is specific for DNA. Although
15 the light attenuation produced by the narrow band 619 nm filter decreased the light intensity,
16 its use ensured that the image was only the result of the EuMac luminescence.

17 Images C and D were obtained with the use of a 29 μsec time delay. The flashlamp was
18 operated at 8Hz; and 760 two msec exposures were summed. Image C was obtained with the
19 UV DAPI cube. The camera summation artifact in image (C) was reduced by the single use of
20 the Adjust Remove background and Adjust Autolevel brightness filters from the Fovea Photo-
21 Shop plug-in (<http://reindeergraphics.com>). Image D was obtained with the UV DAPI cube
22 and the DAPI 450 nm emission filter.

23 Except for the camera summation artifact, image (C) is identical with image (A); yet image
24 (D) is blank. Since the DAPI emission has been extinguished after a 29 μsec delay, it can be
25 concluded that the time-delayed image (C) only contains the europium macrocycle emission.
26 Thus, the use of a unitary luminescence enhancing solution permits imaging including time-
27 gated imaging of the luminescence from the EuMac and other lanthanide(III) complexes with
28 similar lifetimes, such as the TbMac of EXAMPLE XIII, permits the simultaneous detection
29 of conventional fluorophores such as DAPI, and permits the use of time-gating to eliminate
30 any contamination of the EuMac emission by the strong emission produced by the conven-
31 tional fluorophore.

EXAMPLE XXI

SmMac-di-NCS Stained Cells

A. Materials.

(a) SmMac-di-NCS was synthesized according to US Patent 5,696,240, EXAMPLE XXIX B, Step 1.

(b) All other materials are the same as those listed in EXAMPLE XIX and EXAMPLE XX.

B. Procedure

The procedures of EXAMPLE XIX were followed with the substitution of the SmMac-di-NCS for the EuMac-di-NCS.

Figure 13 shows two inverted images of SmMac stained cells that were prepared by centrifugal cytology, treated with $\text{Gd}(\text{TTFA})_3\text{-EtOH}$, and mounted and dried in Clearium. A 60x objective, NA 1.25, was used and the images were binned to 680 x 518 pixels. A Hamamatsu L4634 flashlamp in a special housing was used as the light source. For Figure 13A, the QIM-AGING Retiga-1350 EX CCD camera was kept open for 0.5 sec. with a flash rate of 50 Hz. The DAPI stained nuclei are clearly visible with good maintenance of nuclear detail. Except for one cell in the center near the top, the cytoplasm is not evident. The same microscopic field (Figure 13B) was imaged employing a time delay of 29 μsec . Figure 13B is the sum of eight images, each of which is the sum of one thousand 2 msec. time gated exposures with the flashlamp operated at 8 Hz. In order to avoid overflow artifacts, the Fovea Math. General filter was used to sum four pairs of images and to divide the values of the individual pixels by two. The four pairs were similarly processed to produce two pairs, which were again processed to produce one average image. The uneven background, camera artifact, was lessened by using the Fovea Remove Bkgrnd filter. The black and white levels were stretched by the use of the Fovea contrast filter to bracket the region of the monochrome distribution that contained a significant number of pixels. The luminescence of the samarium macrocycle was much weaker than that of the europium macrocycle. However, as demonstrated in EXAMPLE XX, the DAPI fluorescence is not detectable after a 29 μsec . delay; and the image consists of

1 the total area of the SmMac-di-NCS stained cells. Thus, the use of a unitary luminescence
2 enhancing solution permits imaging including time-gated imaging of the luminescence from
3 the relatively weakly luminescent SmMac and other lanthanide(III) complexes with similar
4 lifetimes, permits the simultaneous detection of conventional fluorophores such as DAPI, and
5 permits the use of time-gating to eliminate any contamination of the SmMac emission by the
6 strong emission produced by the conventional fluorophore.

7 EXAMPLE XXII

8 Luminescence Studies of EuMac-di-NCS Stained Cells Dried from 9 Yttrium(TTFA)₃ Solution 10

11 A. Materials.

12 (a) Y(TTFA)₃-EtOH is an ethanol solution containing 134 μ M of the Y(TTFA)₃ of
13 EXAMPLE III.
14

15 (b) The materials of EXAMPLE XIX with the substitution of Y(TTFA)₃-EtOH for the
16 Gd(TTFA)₃-EtOH of EXAMPLE XIX.

17 B. Procedure 18

19 (a) The procedures of EXAMPLE XIX are followed with the substitution of Y(TTFA)₃-
20 EtOH for the Gd(TTFA)₃-EtOH of EXAMPLE XIX.

21 (b) The cells are observed with a fluorescence microscope under 365 nm excitation pro-
22 vided by a Hamamatsu L4634 flashlamp placed in a special housing (Ref. 13). The light
23 passes through a UV DAPI cube, which does not include an emission filter. A removable,
24 narrow band-pass 619 nm emission filter is located above the cube.
25

26 Two inverted images are obtained of the same field of EuMac-di-NCS stained cells that are
27 prepared by centrifugal cytology, treated with Y(TTFA)₃-EtOH, and mounted and dried in
28 Clearium. A 60x oil objective, NA 1.25, is used and the images are binned to 680 x 518 pixels.
29 The flash lamp is used as the light source. A first image of a single 5 sec exposure of the CCD
30 camera is obtained with the flash lamp operated at 50Hz with a UV DAPI cube and 619 nm
31 emission filter. A second image is the sum of sufficient 2 msec exposures of the CCD camera

1 with the flash lamp operated at 8Hz, a time delay of 29 μ sec, and with only a UV DAPI cube.
2 A time delay system and software supplied by the manufacturer permits the averaging of one
3 thousand 2 msec exposures. According to the manufacturer, the Retiga-1350 EX has an
4 approximately 9 μ sec delay before opening its shutter. The total delay, 29 μ sec, is the sum of
5 camera delay and the 20 μ sec delay produced by the special time-delay box. The conventional
6 first and time-delayed second images are very similar. Thus, cofluorescence occurs with the
7 substitution of yttrium(III) for gadolinium(III).

8 EXAMPLE XXIII

9 Preparation of EuMac-anti-5-BrdU Directly Stained Apoptotic Cells

10 A. Materials.

- 11 (a) The EuMac-Anti-5-BrdU of EXAMPLE XVI.
- 12 (b) The gelatin of the Most Commonly Used Materials.
- 13 (c) The NaN_3 of the Most Commonly Used Materials.
- 14 (d) The Triton X-100 of the Most Commonly Used Materials.
- 15 (e) PFS Wash buffer (Phoenix Flow Systems, San Diego, CA, Catalog No. ABWB13).
- 16 (f) PBS-Azide is an aqueous solution containing 10 mM NaH_2PO_4 , 150 mM NaCl, and
17 0.05% NaN_3 .
- 18 (g) The Gd rinse buffer of EXAMPLE XIX.
- 19 (h) The $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ of EXAMPLE XIX
- 20 (i) The 5% PEG-EtOH solution of the Most Commonly Used Materials.
- 21 (j) Fluorescein labeled anti-5-BrdU (Phoenix Flow systems, San Diego, CA, Fluores-
22 cein~PRB-1 monoclonal antibody, Catalog No. ABFM18).
- 23 (k) Positive and negative control apoptotic cells (Phoenix Flow Systems, San Diego, CA,
24 APO-BRDUTM Kit, Catalog Nos. CC1002 and CC1001, respectively).

1 (l) The aminosilane treated slides of the Most Commonly Used Materials.

2 (m) The Clearium Mounting Medium of the Most Commonly Used Materials.

3
4 B. Procedure

5 (a) This direct staining procedure was based on the standard technique described in the
6 Phoenix Flow Systems APO-BRDU™ Kit (Ref. 32). Parallel flow cytometry measure-
7 ments with fluorescein labeled anti-5-BrdU permitted direct quality control for all of the
8 reagents except the EuMac-mono-NCS labeled anti-5-BrdU. Parallel centrifugal cytology
9 preparations were made with the fluorescein labeled proteins. The cells were allowed to
10 air-dry from the ethanol, because the low surface tension of ethanol produces minimal
11 morphological distortion.

12 (b) A pair of Leif Centrifugal Cytology Buckets (Ref. 33) (Newport Instruments) that fit
13 a Beckman Coulter (Brea, CA) model GPR centrifuge, each of which holds 2 inserts,
14 were assembled with aminosilane treated slides. Four chamber inserts were used.

15 (c) The DNA Labeling solution was prepared according to the APO-BrdU Protocol
16 (Ref. 32).

17 (d) 1 mL aliquots of the positive control cell suspensions (approximately 1×10^6 cells
18 per 1 mL) were transferred to 12 x 75 mm Fisher Scientific flow cytometry centrifuge
19 tubes. The positive control cell suspensions were centrifuged at 300 g for 5 min before
20 removing the 70% (v/v) ethanol supernatant by aspiration.

21 (e) The cells were washed twice with 1 mL of Phoenix Flow Systems wash buffer (Ref.
22 32). Each wash was carried out by centrifugation at 300 g for 5 min and the supernatant
23 was removed by aspiration.

24 (f) The apoptotic breaks were tailed with 5-BrdU by addition of 50 μ L of DNA Labeling
25 solution and incubation at 37 °C for 60 min.

26 (g) The cells were then washed twice by centrifugation for 5 min with 0.5 mL of Gd
27 rinse buffer, and the supernatant was removed as before.

28
29
30
31

1 (h) The cell pellet was resuspended in 0.1 mL of a solution containing 40 $\mu\text{g/mL}$ of
2 EuMac-anti-5-BrdU in Gd rinse buffer. The tubes were wrapped with aluminum foil and
3 incubated in the dark for 30 min at room temperature.

4 (i) After the 30 min incubation, 0.5 mL of the Gd Rinse Buffer was added to the staining
5 solution. The cell suspension was centrifuged and the supernatant removed, as before.
6

7 (j) The wash treatment of step (i) was repeated.

8 (k) The cells were resuspended with 0.5 mL of Gd Rinse Buffer, or with the volume of
9 buffer required to obtain the desired cell density for centrifugal cytology with the four
10 chamber Leif Buckets.
11

12 (l) The cells were centrifuged at 300 g for 5 min in Leif Buckets and the supernatant was
13 removed by aspiration.

14 (m) 100 μL of the 5% PEG-EtOH solution was added to the fixative inlet of the centrif-
15 ugal cytology sample chambers and sedimented onto the slide-attached cells by accelerat-
16 ing the centrifuge for approximately 30 sec. The supernatant was then removed by
17 aspiration.
18

19 (n) The slides were removed from the Leif Buckets, rinsed twice with ethanol and air
20 dried.

21 (o) The cell monolayer was flooded with 2 drops of 134 μM $\text{Gd}(\text{TFFA})_3\text{-EtOH}$ and air
22 dried.
23

24 (p) The slide-bound cells were rinsed twice with ethanol, removing excess liquid each
25 time, and air dried.

26 (q) 30 μL Clearium Mounting Medium was pipetted onto the cell area, making sure that
27 all cells were covered.
28

29 (r) The solvent was removed from the Clearium by mild heat generated with a heat gun.

30 (s) The cells were observed with a fluorescent microscope under 365 nm excitation pro-
31 vided by continuous illumination with a 100 watt mercury-xenon arc. The light passed

1 through a UV DAPI cube, which did not include an emission filter, and then through a
2 narrow band-pass 619 nm emission filter located above the cube. The exposure was 30
3 sec. A 60x oil objective, NA 1.25, was used and the image of the cells was binned to 640
4 x 518 pixels. The image shown in Figure 14 was slightly over exposed in order to show
5 the unlabeled cells.

6 (t) Therefore, as demonstrated by the detection of apoptosis, it has now been possible
7 with only minimal changes from presently existing protocols to produce preparations of
8 cells directly stained with europium labeled antibodies, and to obtain intensified emission
9 from the stained cells after drying from a unitary luminescence enhancing solution con-
10 taining a different lanthanide ion, in the presence of an amount of TTFA ligand in excess
11 of that needed to complex with the EuMacs. The use of ethanol as the low surface tension
12 solvent, ethanol, of the unitary luminescence enhancing solution and absence of the deter-
13 gent required for formation and maintenance of the previous micellar Lanthanide
14 Enhanced Luminescence solution (Refs. 5,6) resulted in the morphology of the cells
15 remaining intact.

16 EXAMPLE XXIV

17 Preparation of SmMac-anti-5-BrdU or Other LnMac-anti-5-BrdU Directly 18 Stained Apoptotic Cells

19 A. Materials.

20 (a) The SmMac-Anti-5-BrdU of EXAMPLE XXVII or other LnMac-anti-BrdU.
21

22 B. Procedure

23 (a) The procedures of EXAMPLE XXIII are followed with the substitution of the of
24 SmMac-Anti-5-BrdU or other LnMac-Anti-5-BrdU for EuMac-Anti-5BrdU.
25

26 (b) The SmMac-Anti-5-BrdU labeled cells are observed with a fluorescence microscope
27 under 365 nm excitation provided by continuous illumination with a 100 watt mercury-
28 xenon arc. The light is passed through a UV DAPI cube, which does not include an emis-
29 sion filter, and then through a 630 to 660 nm, half maximum cut-off points, band-pass
30 emission filter located above the cube. Test images are made to determine the optimum
31

1 exposure time. A 60x oil objective, NA 1.25, is used and the image of the cells is binned
2 to 640 x 518 pixels. The black and white levels of the image are stretched by the use of
3 the Fovea contrast filter to bracket the region of the monochrome distribution that con-
4 tains a significant number of pixels and are adjusted to weakly show the unlabeled cells.

5 (c) Therefore, as demonstrated by the detection of apoptosis, it has now been possible
6 with only minimal changes from presently existing protocols to produce preparations of
7 cells directly stained with antibodies labeled with samarium(III) and to intensify their
8 emission after drying from a unitary luminescence enhancing solution containing a differ-
9 ent lanthanide ion in the presence of an amount of TTFA ligand in excess of that needed
10 to complex with the EuMacs. The use of a low surface tension solvent, ethanol, permits
11 air drying without impairing the morphology of the cells.

12 (d) Alternatively, the composition of the unitary luminescence enhancement solution is
13 optimized according to the procedures of EXAMPLE XIII.

14 (e) Alternatively, the other LnMac-Anti-5-BrdU labeled cells are visualized according to
15 the procedures of EXAMPLE XV.

16 (f) Or, alternatively, an enhancer for terbium(III) or other lanthanide ion that excites
17 above approximately 325 nm, and is suitable for use as a constituent of a unitary lumines-
18 cence enhancing solution, can be employed with conventional microscope optics.
19
20

21 The use of ethanol as the low surface tension solvent, ethanol, of the unitary luminescence
22 enhancing solution and absence of the detergent required for formation and maintenance of
23 the previous micellar Lanthanide Enhanced Luminescence solution (Refs. 5,6) results in the
24 morphology of the cells remaining intact.

25 EXAMPLE XXV

26 Preparation of EuMac-anti-5-BrdU Directly Stained S Phase Cells

27 A. Materials.

28 (a) The EuMac-Anti-5-BrdU of EXAMPLE XVI.
29
30
31

(b) The following components of the Phoenix Flow Systems (San Diego, CA) ABSOLUTE-S™ (Ref. 34):

(i) 5-BrdU tailed cells, which are the Phoenix Flow Systems' Post UV irradiation reaction control cells, Part Number ASPC11. These cells have already formed DNA breaks that are tailed with 5-BrdU in the presence of TdT.

(ii) Wash Buffer, Part Number ASWB15.

(iii) Reaction Buffer, Part Number ASRXB16.

(iv) TdT Enzyme, Part Number ASTD17.

(v) Br-dUTP, Part Number ASBU18.

(vi) The Fluorescein labeled anti-5-BrdU of EXAMPLE XXIII.

(c) The Gd rinse buffer of EXAMPLE XIX.

(d) The 5% PEG-EtOH solution of the Most Commonly Used Materials.

(e) The Clearium Mounting Medium of the Most Commonly Used Materials.

B. Procedure

This direct staining procedure was based on the SBIP™ (Strand Break Induced Photolysis) technique (Ref. 35) described in the Phoenix Flow Systems ABSOLUTE-S™ Kit (Ref. 34). Parallel flow cytometry measurements with fluorescein labeled anti-5-BrdU permitted direct quality control for all of the reagents except the EuMac-mono-NCS labeled anti-5-BrdU. Parallel centrifugal cytology preparations were made with the fluorescein labeled antibody. The cells were allowed to air-dry from ethanol, because the low surface tension of ethanol produces minimal morphological distortion.

This protocol started with photolysis of the BrdU labeled DNA and is followed by tailing by the addition of 5-BrdU with terminal deoxytransferase.

(a) The 5-BrdU incorporated cells were resuspended by swirling the container containing the cells.

1 (b) 1 mL of the 5-BrdU incorporated cells was transferred to 12x75 mm tubes.

2
3 (c) The cells were centrifuged for 5 min. at 300 g followed by the removal of the super-
4 natant by aspiration, being careful not to disturb the cell pellet.

5 (d) 2 mL of the Wash Buffer was added; the cells were resuspended and centrifuged for 5
6 min at 300 g, followed by the removal of the supernatant by aspiration, being careful not
7 to disturb the cell pellet.

8 (e) The pellet was resuspended in 0.5 mL of Wash Buffer, making sure to free any cells
9 that may have adhered to the tube sides during washing.

10
11 (f) The tube containing the cells was placed on the irradiating surface of the light box and
12 illuminated for 5 min on high setting using a Fotodyne UV21 DNA transilluminator
13 (Fotodyne inc., Hartland, WI).

14 (g) After illumination, 1 mL of Wash Buffer was added to the tubes; the cells were resus-
15 pended and then centrifuged for 5 min at 300 g, and the supernatant removed by aspira-
16 tion, being careful not to disturb the cell pellet.

17
18 (h) The DNA Labeling Solution was prepared according to the vendor's instructions,
19 depending on the number of assays being performed as described in the reference (Ref.
20 34). For example, 100 μ L of TdT Reaction Buffer, 7.5 μ L of TdT Enzyme, 80 μ L of
21 BrdUTP and 322.5 μ L of distilled H₂O were mixed together for a total volume of 510 μ L.

22 (i) The photolysis induced breaks were tailed with 5-BrdU by the addition of 50 μ L of
23 DNA Labeling solution, and incubated for 60 min at 37 °C in a temperature controlled
24 water bath. The cells were resuspended by shaking every 15 min.

25
26 (j) The cells were washed twice by centrifugation for 5 min with 0.5 mL of Gd rinse
27 buffer, and the supernatant removed as before.

28 (k) The cell pellet was resuspended in 0.1 mL of 40 μ g/mL of EuMac-anti-5-BrdU; the
29 tubes were wrapped with aluminum foil and incubated in the dark for 30 min at room
30 temperature.

31

1 (l) After the 30 min incubation, 0.5 mL of Gd Rinse Buffer was added to the staining
2 solution. The cell suspension was centrifuged and the supernatant removed, as before.

3 (m) The wash treatment of step (l) was repeated.
4

5 (n) A pair of Leif Centrifugal Cytology Buckets (Ref. 33) (Newport Instruments) that fit
6 a Beckman Coulter (Brea, CA) model GPR centrifuge, each of which holds 2 inserts,
7 were assembled with aminosilane treated slides. Four chamber inserts were used.

8 (o) The cells were resuspended with 0.5 mL of Gd rinse buffer, or with the volume of
9 buffer required to obtain the desired the cell density for centrifugal cytology with the four
10 chamber Leif Buckets.

11 (p) The cells were centrifuged at 300 g for 5 min in Leif Buckets and the supernatant
12 was removed by aspiration.
13

14 (q) 100 μ L of 5% PEG-EtOH solution was added to the fixative inlet of the centrifugal
15 cytology sample chambers and sedimented onto the slide-attached cells by centrifugation.
16 The supernatant was then removed by aspiration.

17 (r) The slides were removed from the Leif Buckets, rinsed twice with ethanol and air
18 dried.
19

20 (s) The cell monolayer was flooded with 2 drops of 134 μ M Gd(TTFA)₃ in ethanol and
21 air dried.
22

23 (t) The slide-bound cells were rinsed twice with ethanol, removing excess liquid each
24 time, and air dried.

25 (u) 30 μ L Clearium Mounting Medium was pipetted onto the cell area, making sure all
26 cells were covered.
27

28 (v) The solvent was removed from the Clearium by mild heat generated with a heat gun.

29 (w) The cells were observed with a fluorescence microscope equipped with the 60 x oil
30 immersion lens. The 365 nm excitation was provided by continuous illumination with a
31 100 watt mercury-xenon arc. The exposure was for 30 sec. The light passed through a UV

1 DAPI cube, which did not include an emission filter. A removable narrow band-pass 619
2 nm emission filter was mounted before the camera. The image shown in Figure 15 was
3 slightly overexposed to show the small dark granules in some of the cells, which are the
4 islands of initial DNA synthesis. The image of the cells was binned to 680 x 518 pixels.

5 (x) Therefore, as demonstrated by the detection of S phase, it has now been possible with
6 only minimal changes from presently existing protocols to produce preparations of cells
7 directly stained with europium-labeled antibodies and to intensify their emission after
8 drying from a unitary luminescence enhancing solution containing a different lanthanide
9 ion.

10
11 The use of ethanol as the low surface tension solvent, ethanol, of the unitary luminescence
12 enhancing solution and absence of the detergent required for formation and maintenance of
13 the previous micellar Lanthanide Enhanced Luminescence solution (Refs. 5,6) resulted in the
14 excellent morphology of the cells including the visualization of the islands of initial DNA
15 synthesis.

16 EXAMPLE XXVI

17 Preparation of SmMac-anti-5-BrdU or Other LnMac-anti-5-BrdU Directly 18 Stained S Phase Cells

19 A. Materials

20
21 (a) The SmMac-Anti-5-BrdU of EXAMPLE XVII or other LnMac-anti-5-BrdU.

22 A. PROCEDURES.

23
24 (a) The procedures of EXAMPLE XXV are followed with the substitution of the
25 SmMac-Anti-5-BrdU or other LnMac-anti-5-BrdU for the EuMac-Anti-5BrdU.

26
27 (b) The SmMac-Anti-5-BrdU labeled cells are observed with a fluorescence microscope
28 equipped with the 60 x oil immersion lens. The 365 nm excitation is provided by continu-
29 ous illumination with a 100 watt mercury-xenon arc. Test images are made to determine
30 the optimum exposure time. The light is passed through a UV DAPI cube, which does not
31 include an emission filter. A removable 630 to 660 nm, half maximum cut-off points,

band-pass emission filter is mounted before the camera. After the black and white levels are stretched by the use of the Fovea contrast filter to bracket the region of the monochrome distribution containing a significant number of pixels, the resulting image shows small dark granules in some of the cells. These are the islands of initial DNA synthesis. The image of the cells is binned to 680 x 518 pixels.

(c) Therefore, as demonstrated by the detection of S phase, it has now been possible with only minimal changes from presently existing protocols to produce preparations of cells directly stained with samarium-, europium- or other lanthanide-labeled antibodies, and to intensify their emission after drying from a unitary luminescence enhancing solution containing a different lanthanide ion.

(d) Alternatively, the other LnMac-Anti-5-BrdU labeled cells are visualized according to the procedures of EXAMPLE XV.

(e) Or, alternatively, an enhancer for terbium(III) or other lanthanide ion that excites above approximately 325 nm, and is suitable for use as a constituent of a unitary luminescence enhancing solution, can be employed with conventional microscope optics.

EXAMPLE XXVII

Preparation of SmMac-Streptavidin

A. Materials.

(a) The SmMac-mono-NCS of EXAMPLE XVII.

(b) The 1.5 M $\text{NH}_2\text{OH}\cdot\text{HCl}$ (pH 8.5) of the most commonly used materials.

(c) The Streptavidin of EXAMPLE VIII.

B. Procedure

(a) The procedures of EXAMPLE VIII are followed with the substitution of the SmMac-mono-NCS for the EuMac-mono-NCS.

(b) The UV spectrum of the conjugate has a strong absorption at 260 nm, which shows

1 the presence of SmMac coupled to streptavidin.

2 EXAMPLE XXVIII

3
4 Preparation of EuMac-Streptavidin Stained Apoptotic Cells to which
5 Biotin-anti-5-BrdU had been Bound

6 A. Materials.

7
8 (a) The EuMac-Streptavidin of EXAMPLE VIII.

9 (b) Biotin-anti5-BrdU, the biotin conjugate of anti5-BrdU (Phoenix Flow Systems, San
10 Diego, CA, Catalog No. PRBBIOA).

11 (c) Materials b through m of EXAMPLE XXIII.

12
13 B. Procedure

14 (a) 1 mL aliquots of the control cell suspensions (approximately 1×10^6 cells per 1 mL)
15 were transferred to 12 x 75 mm Fisher Scientific or 1.5 mL Eppendorf tube (Brinkmann
16 Instruments, Westbury, NY, Catalog No. 22 36 320-4) flow cytometry centrifuge tubes of
17 the Most Commonly Used Materials. The positive control cell suspensions were centri-
18 fugal at 300 g for 5 min to remove the 70% (v/v) ethanol supernatant by aspiration.

19
20 (b) The cells were washed twice by centrifugation at 300 g for 5 min with 1 mL of the
21 Phoenix Flow Systems wash buffer, followed by removal of the supernatant by aspira-
22 tion.

23 (c) The apoptotic breaks were tailed with 5BrdU by addition of 50 μ L of DNA Labeling
24 solution and incubation at 37 °C for 60 min.

25
26 (d) The cells were then washed twice by centrifugation for 5 min with 0.5 mL of Gd rinse
27 buffer. The supernatant removed as before.

28 (e) The cell pellet was resuspended in 0.1 mL of 10 μ g/mL Biotin-anti5-BrdU, the tubes
29 were wrapped with aluminum foil and incubated in the dark for 30 min at room tempera-
30 ture.

31

1 (f) The biotin labeled cell suspension was washed twice with 0.5 mL Gd Rinse Buffer by
2 centrifugation at 300 g for 5 min and the supernatant removed by aspiration, being careful
3 not to disturb the cell pellet.

4 (g) The cell pellet was resuspended in 0.1 mL of a 40 $\mu\text{g/mL}$ EuMac-Streptavidin stain-
5 ing solution, the tubes wrapped with aluminum foil, and incubated in the dark for 30 min
6 at room temperature.

7
8 (h) After the 30 min incubation, 0.5 mL Gd Rinse Buffer was added to the staining solu-
9 tion. The cell suspension was centrifuged and the supernatant removed, as before.

10 (i) The wash treatment of step (h) was repeated.

11
12 (j) The cells were resuspended with 0.5 mL of Gd Rinse Buffer, or with the volume
13 required to obtain the desired cell density for centrifugal cytology with the four chamber
14 Leif Buckets.

15 (k) The cells were centrifuged at 300 g for 5 min. in Leif Buckets and the supernatant
16 removed by aspiration.

17
18 (l) 100 μL of 5% PEG-EtOH solution was added to the fixative inlet of the centrifugal
19 cytology sample chambers and sedimented onto the slide-attached cells by accelerating
20 the centrifuge for approximately 30 sec. The supernatant was then removed by aspiration.

21 (m) The slides were removed from the Leif Buckets, rinsed twice with ethanol and air
22 dried.

23 (n) The cell monolayer was flooded with 2 drops of 134 μM $\text{Gd}(\text{TTFA})_3\text{-EtOH}$ and air
24 dried.

25
26 (o) The slide-bound cells were rinsed twice with ethanol, removing excess liquid each
27 time, and air dried.

28 (p) 30 μL Clearium Mounting Medium was pipetted onto the cell area, making sure all
29 cells were covered.

30
31 (q) The solvent was removed from the Clearium by mild heat generated with a heat gun.

(r) The cells were observed with a fluorescence microscope under 365 nm excitation provided by continuous illumination with a 100 watt mercury-xenon arc. The light passed through a UV DAPI cube, which did not include an emission filter, and then through a narrow band-pass 619 nm emission filter located above the cube. The exposure was 30 sec. A 60x oil objective, NA 1.25, was used and the images of the cells were binned to 640 x 518 pixels. The image shown in Figure 16 is slightly over exposed in order to show the unlabeled cells.

(s) Therefore, as demonstrated by the detection of apoptosis, it has now been possible with only minimal changes from presently existing protocols to produce preparations of cells indirectly labeled with europium-labeled antibodies, and to intensify their emission after drying from a unitary luminescence enhancing solution containing a different lanthanide ion. The use of ethanol as the low surface tension solvent, ethanol, of the unitary luminescence enhancing solution and absence of the detergent required for formation and maintenance of the previous micellar Lanthanide Enhanced Luminescence solution (Refs. 5,6) resulted in the maintenance of the morphology of the cells.

EXAMPLE XXIX

Preparation of EuMac-Streptavidin Stained S Phase Cells to which Biotin-anti-5-BrdU has been Bound

A. Materials

- (a) The EuMac-Streptavidin of EXAMPLE VIII.
- (b) Biotin-anti5-BrdU, the biotin conjugate of anti5-BrdU (Phoenix Flow Systems, San Diego, CA, Catalog No. PRBBIOA).
- (c) Materials b through e of EXAMPLE XXV

B. Procedure

This indirect staining procedure was based on the direct SBIPTM (Strand Break Induced Photolysis) technique (Ref. 35) described in the Phoenix Flow Systems ABSOLUTE-STM Kit

1 (Ref. 34). This protocol starts with photolysis of the BrdU labeled DNA and is followed by
2 tailing by the addition of 5-BrdU with terminal deoxytransferase.

3 (a) Procedures a through j of EXAMPLE XXV.

4
5 (b) Procedures e through q of EXAMPLE XXVIII.

6 (c) The cells were observed with a fluorescence microscope under 365 nm excitation
7 provided by continuous illumination with a 100 watt mercury-xenon arc. The light passed
8 through a UV DAPI cube, which did not include an emission filter, and then through a
9 narrow band-pass 619 nm emission filter located above the cube. The exposure was 10
10 sec. A 60x oil objective, NA 1.25, was used and the image of the cells was binned to 640
11 x 518 pixels. The image is shown in Figure 17.

12 (d) Therefore, as demonstrated by the detection of S phase, it has now been possible with
13 only minimal changes from presently existing protocols to produce preparations of cells
14 indirectly labeled with antibodies labeled with europium or other lanthanide ion and to
15 intensify their emission after drying from a unitary luminescence enhancing solution con-
16 taining a different lanthanide ion. The use of ethanol as the low surface tension solvent,
17 ethanol, of the unitary luminescence enhancing solution and absence of the detergent
18 required for formation and maintenance of the previous micellar Lanthanide Enhanced
19 Luminescence solution (Refs. 5,6) resulted in the maintenance of the morphology of the
20 cells

21 EXAMPLE XXX

22 Measurement of Human Follicle Stimulating Hormone (FSH) in the Dry 23 State

24
25 The procedures of Example XI of US 6340744 (Ref. 5) are modified by the substitution of
26 TRIS for hexamethylenetetramine, HMTA, and of the Gd(TTFA)₃-EtOH of EXAMPLE V for
27 the optimized-cofluorescence matrix, followed by removal of the solvent.

28 A. Materials 29

30 (a) The EuMac-mono-NCS of the Most Commonly Used Materials.

31

1 (b) A monoclonal antibody, M94167, specific for the β -subunit of human FSH, commer-
2 cially available from Fitzgerald Industries International, Inc., Concord, MA, Catalog No.
3 10-F25, 1999.

4 (c) A monoclonal antibody, M607109, that recognizes a compatible epitope on human-
5 FSH not located on the β -subunit of human FSH, commercially available from Fitzgerald
6 Industries International, Inc., Catalog No. 10-F15. 1999.

7
8 (d) Intact human Follicle Stimulating Hormone (hFSH), commercially available from
9 Fitzgerald Industries International, Inc., Catalog No. 30-AF25, 1999.

10 (e) Washing Buffer: In a 1L volumetric flask, the following are added: 50 mmol (6 g) of
11 the TRIS of the Most Commonly Used Materials), 154 mmol (9 g) of sodium chloride
12 (Aldrich, St. Louis, MO, Catalog No. 204439), 0.5 mL of Tween 20 (Aldrich, Catalog
13 No. 27,434-8), and 900 mL of water. The solution is adjusted to pH 7.75 with hydrochlo-
14 ric acid and water is added to bring the volume to 1L.

15
16 (f) Assay Buffer: In a 1L volumetric flask, the following are added: 50 mmol (6 g) of
17 TRIS of the Most Commonly Used Materials, 154 mmol (9 g) of sodium chloride (Ald-
18 rich, Catalog No. 204439), 5 g of bovine serum albumin (Sigma, St. Louis, MO, Catalog
19 No. B 4267), 0.5 g of bovine IgG (Sigma, Catalog No. I 5506), 0.1 g of Tween 40 (Ald-
20 rich, Catalog No. 27,435-6), and 900 mL of water. The solution is adjusted to pH 7.75
21 with hydrochloric acid and water is added to bring the volume to 1L.

22 B. Procedure

23 (a) The derivatization, or conjugation, of the EuMac-mono-NCS with the M607109
24 monoclonal antibody is achieved by the procedures described in EXAMPLE XVI, with
25 the replacement of the anti-5-BrdU of the Most Commonly Used Materials by the mono-
26 clonal antibody M607109. The europium-labeled M607109 is centrifuged for 2 min. at
27 17,000 g (Hermle Z 180 Microcentrifuge) to remove any antibody aggregates, and stored
28 at 4 °C until use.

29
30 (b) Polystyrene microtiter strips (Immuno Module Maxisorp; Nalge Nunc International,
31 Naperville, IL, Catalog. No. 469914) are coated overnight, at 4 °C, with 2 μ g of the

1 M94167 monoclonal antibody in 100 μ L of PBS per well. Subsequently, the strips are
2 incubated for 45 min at 37 °C with 200 μ L of PBS containing bovine serum albumin (10
3 g/L) and then washed four times with the washing buffer.

4 (c) Graded amounts of the antigen (hFSH) in 100 μ L of Assay Buffer are added to the
5 M94167-coated wells and allowed to react on an orbit shaker at 500 rpm for 90 min at 22
6 °C.

7
8 (d) The plates are washed six times with the washing buffer.

9 (e) 25 ng of europium-labeled M607109 in 100 μ L of assay buffer are added to each well
10 and the strips are incubated for 30 min at 22 °C on an orbit shaker (500 rpm).

11
12 (f) The plates are washed six times with the washing buffer.

13 (g) 100 μ L of Gd(TTFA)₃-EtOH are added to each well and allowed to react with the
14 intact europium-labeled M607109 for 10 min on an orbit shaker (500 rpm).

15
16 (h) The wells are air dried and the bottoms are cut-out

17 (i) The fluorescence is measured for 5 sec in a SLM-8000 fluorometer with the emission
18 monochromator set at 618 nm and the emission slit adjusted to have a 10 nm band width
19 at half maximum. The excitation is at 365 nm with a 16 nm band width at half maximum.

20
21 (j) The signal to noise ratio at 8 ng/L of FSH is higher than 1,000 and the maximum con-
22 centration measurable by the SLM-8000 exceeds 10,000 ng/L. Thus, the performance of
23 the system described here is better than immunoenzymetric and immunoradiometric
24 assays, even though it is slightly inferior to time-resolved immunofluorescence assays.

25 (k) In contrast to the examples given in Soini et al., US Patent 4,587,233, Method for
26 Quantitative Determination of a Biospecific Affinity Reaction, 1986; and to the descrip-
27 tion of similar uses of lanthanide luminescent labels in I. Hemmila et al. (1994) (Ref. 37),
28 because of the use of a unitary luminescence enhancing solution the analyte of this inven-
29 tion can be measured in a conventional fluorometer without requiring the additional steps
30 of removal of the lanthanide(III) from a first complex and the formation of a second com-
31 plex in solution prior to measurement. The performance of the system described here can

1 be improved to be better than that of the DELFIA reagents which are optimized for the
2 Arcus 1230. The signal is enhanced by the coating of the sample with $\text{Gd}(\text{TTFA})_3$. Since
3 the emitting species is bound to a solid surface, the depth of focus and optical volume of
4 an instrument can be minimized, which in turn minimizes background noise from the
5 solution.

8 EXAMPLE XXXI

9 Time-Gated Measurement of Human Follicle Stimulating Hormone 10 (FSH) in the Dry State

11 A. Procedure

12 (a) The procedures of EXAMPLE XXX are repeated through step (g).

14 (b) The wells are air dried.

16 (c) The microtiter tray is mounted on Varian Cary Eclipse microplate reader accessory.
17 Time-resolved fluorescence is measured for 1 sec in a Varian Cary Eclipse spectrofluoro-
18 meter in time-gated mode. The emission monochromator is set at 618 nm and the emis-
19 sion slit adjusted to have a 10 nm band width at half maximum. The excitation is at 365
20 nm with a 16 nm band width at half maximum.

21 (d) In contrast to the examples given in Soini et al., US Patent 4,587,233, Method for
22 Quantitative Determination of a Biospecific Affinity Reaction, 1986; and to the descrip-
23 tion of similar uses of lanthanide luminescent labels in I. Hemmila et al. (1994) (Ref. 37),
24 because of the use of a unitary luminescence enhancing solution the analyte of this inven-
25 tion can be measured in a conventional fluorometer without requiring the additional steps
26 of removal of the lanthanide(III) from a first complex and the formation of a second com-
27 plex in solution prior to measurement. The performance of the system described here can
28 be improved to be better than that of the DELFIA reagents which are optimized for the
29 Arcus 1230. The signal is enhanced by the coating of the sample with $\text{Gd}(\text{TTFA})_3$. Since
30 the emitting species is bound to a solid surface, the depth of focus and optical volume of
31 an instrument can be minimized, which in turn minimizes background noise from the

1 solution.

2 EXAMPLE XXXII

3 A Competitive Immunological Determination of Insulin in the Dry State

4 The procedures of Example XI of US 6340744 (Ref. 5) are modified by the substitution of
5 TRIS for HMTA, of the Gd(TTFA)₃-EtOH of EXAMPLE V for the optimized-cofluorescence
6 matrix, and subsequent removal of the solvent.
7

8 A. Materials

9 (a) The EuMac-mono-NCS of the Most Commonly Used Materials.

10 (b) Insulin (Sigma Biochemicals and Reagents for Life Science Research, St. Louis, MO,
11 Catalog No. I 0259).
12

13 (c) A monoclonal antibody against human insulin (anti-insulin) is obtained from Fitzger-
14 ald Industries International, Inc., Concord, MA, Catalog No. 10-I30, 1999).
15

16 (d) The Washing Buffer of EXAMPLE XXX.
17

18 (e) The Assay Buffer of EXAMPLE XXX.

19 B. Procedure

20 (a) The derivatization, or conjugation, of the EuMac-mono-NCS with insulin is achieved
21 by the procedures described in EXAMPLE XVI, with the replacement of the anti-5-BrdU
22 of the Most Commonly Used Materials by insulin. The europium-labeled insulin, EuMac-
23 Insulin, is centrifuged for 2 min at 17,000 g (Hermle Z 180 Microcentrifuge) to remove
24 any protein aggregates, and stored at 4 °C until use.
25

26 (b) Polystyrene microtiter strips (Immuno Module Maxisorp; Nalge Nunc International,
27 Naperville, IL, Catalog No. 469914) are coated overnight, at 4 °C, with 2 µg of the anti-
28 insulin monoclonal antibody in 100 µL of PBS per well. Subsequently, the strips are incu-
29 bated for 45 min at 37 °C with 200 µL of PBS containing bovine serum albumin (10 g/L)
30 and then washed four times with the washing buffer.
31

1 (c) 10 μ L of EuMac-Insulin (20 ng) and 10 μ L of insulin standards (0, 10, 50, 200, 1,000
2 and 10,000 ng) in 100 μ L of Assay Buffer are added to the monoclonal antibody coated
3 wells and allowed to react on an orbit shaker at 500 rpm for 90 min at 22 °C.

4 (d) The plates are washed six times with the washing buffer.

5
6 (e) 100 μ L of Gd(TTFA)₃-EtOH are added to each well and allowed to react with the
7 EuMac-Insulin for 10 min on an orbit shaker (500 rpm).

8 (f) The wells are air dried.

9
10 (g) The microtiter tray is mounted on Varian Cary Eclipse microplate reader accessory.
11 Time-resolved luminescence is measured for 1 sec in a Varian Cary Eclipse spectrofluoro-
12 meter in time-gated mode. The emission monochromator is set at 618 nm and the emis-
13 sion slit adjusted to have a 10 nm band width at half maximum. The excitation is at 365
14 nm with a 16 nm band width at half maximum.

15 (h) According to the competitive determination principle (Ref. 36) the emission intensity
16 of the sample decreases, as the amount of "cold" insulin increases.

17
18 (i) In contrast to the examples given in Soini et al., US Patent 4,587,233, Method for
19 Quantitative Determination of a Biospecific Affinity Reaction, 1986; and to the descrip-
20 tion of similar uses of lanthanide luminescent labels in I. Hemmila et al. (1994) (Ref. 37),
21 because of the use of a unitary luminescence enhancing solution the analyte of this inven-
22 tion can be measured in a conventional fluorometer without requiring the additional steps
23 of removal of the lanthanide(III) from a first complex and the formation of a second com-
24 plex in solution prior to measurement. The performance of the system described here can
25 be improved to be better than that of the DELFIA reagents which are optimized for the
26 Arcus 1230. The signal is enhanced by the coating of the sample with Gd(TTFA)₃. Since
27 the emitting species is bound to a solid surface, the depth of focus and optical volume of
28 an instrument can be minimized, which in turn minimizes background noise from the
29 solution.

30 EXAMPLE XXXIII

Comparative Genomic Hybridization

Introduction: The procedures for comparative genomic hybridization and analysis generally follow a course of nine broadly defined steps: (1) processing nucleic acid material including nucleic acids or oligonucleotides to generate populations of homogeneous nucleic acid fragments (typically complementary DNA, cDNA) suitable for printing onto substrate; (2) preparation of a receiving surface member with nucleic acid sequences of interest at one or more identifiable positions on a the receiving surface member; (3) isolation of two samples of nucleic acids from which hybridizing sample and reference specimens are derived; (4) synthesizing sample and reference cDNAs by copying either mRNA or DNA; (5) labeling sample and reference cDNAs with labels (presently fluorescent) that would permit them to be distinguished either during their synthesis or subsequent to their synthesis; (6) hybridizing a mixture of the labeled sample and reference cDNAs to the DNA sequences in the form of chromosomes or as an array of DNA containing spots on a receiving surface member; (7) preparation of the hybrids for visualization; (8) image acquisition of hybridization and (9) image analysis. The nucleic acid sequences of interest of step (2) can either exist as sequences present on chromosomes or as purified samples of polynucleotides.

The novel parts of the subsequent examples concern the labeling (step 5), preparation for visualization (step 7), and image acquisition (step 8). Since the rest of the procedures have been published as patents (Refs. 38, 39, 40, 41, 42, and 43), patent applications (Refs. 44, 45), articles (46, 47, 48), and web pages (Refs. 49, 50); these referenced CGH procedures are well understood by one of ordinary skill in the art.

As will be demonstrated by the following Examples, the labeling of sample and reference cDNAs with an energy transfer acceptor lanthanide(III) complex can either be performed for a direct assay where the complex is covalently bound to the cDNA or for an indirect assay where the energy transfer acceptor lanthanide(III) complex is bound to an analyte-binding species that is specific for a label. Besides the standard labels, such as biotin, this label can be a modified nucleotide, such as 5-BrdU.

EXAMPLE XXXIV

Preparation of cDNA labelled with a LnMac

1 The covalent labeling of DNA with a fluorophore or lumiphore can be performed by: 1)
2 covalent coupling of the label to a nucleotide and subsequent enzymatic incorporation of the
3 nucleotide into cDNA (Ref. 51); 2) enzymatic incorporation of a nucleotide with a reactive
4 functionality into cDNA and subsequent covalent coupling of a label with the reactive func-
5 tionality (Refs 52 and 53); and 3) covalent attachment of a preformed labeled carrier (Ref. 54)

6 A. Materials

- 7 (a) The EuMac-5-deoxyuridine triphosphate (Formula V) of EXAMPLE XXI of US
8 Patent 6,340,744.
9
10 (b) The SmMac-5-deoxyuridine triphosphate of EXAMPLE XXI of US Patent
11 6,340,744.
12
13 (c) The procedure of EXAMPLE XXI of US Patent 6,340,744 is repeated with the
14 replacement of the europium(III) by terbium(III) to produce TbMac-5-deoxyuridine.
15
16 (d) Venipuncture Human blood sample obtained from a volunteer.
17
18 (e) PUREGENE® DNA Purification Kit for whole blood or bone marrow (Gentra Sys-
19 tems Inc., Minneapolis MN, Catalog No. D-5500).
20
21 (f) Human Genomic DNA (Promega, Madison WI, Female Catalog No. G1521; Male
22 Catalog No. G1471).
23
24 (g) SYBR® Gold Nucleic Acid Gel Stain (Catalog No. S-11494)
25
26 (h) Aminoallyl-dUTP sodium salt (aa-dUTP) Sigma, Catalog No. A0410

24 B. Procedure

- 25 (a) Genomic DNAs are extracted from the leukocytes present in the blood using the
26 Puregene DNA Purification Kit. From 0.4 mL, approximately 150 µg DNA is prepared.
27 Alternatively, human genomic DNA is purchased from Promega.
28
29 (b) The DNA is sonicated prepared for labeling as described in Ref. 50 Section 6.0,
30 "Labeling of DNA using Random Priming" steps 1 through 5. After sonication, the num-
31 ber of base pairs for the fragments determined by electrophoresis on a small 1% agarose

1 gel should range from 300 to 2000.

2
3 (c) The samples are stored at -80°C.

4 (d) The DNA samples are denatured by boiling for 5 minutes on a heat block at 95°C,
5 and then are snapped cooled on ice for 10 minutes.

6
7 (e) Covalent labeling of an oligonucleotide with a LnMac: The procedures of Tasara et
8 al. (Ref. 51) for the production of labeled templates are followed with the substitution of
9 a LnMac-dUTP for the modified dNTP analogs employed by Tasara et al., including
10 those described in Ref. 51. Alternatively, the "Labeling of DNA using Random Priming"
11 protocol of the Jan Dumanski's Research Group (Ref. 50) can be employed with the
12 replacement of the cyanine dye labeled dNTP with a LnMac-dUTP.

13 (f) The LnMac-mono-NCS is covalently coupled to nucleotides that have previously
14 been incorporated with a reactive functionality. DeRisi described (Ref. 53) the incorpora-
15 tion by reverse transcriptase of the sodium salt of 5-[3-amino-allyl]-2'-deoxyuridine 5'-
16 triphosphate (aa-dUTP) into cDNA. The intensity of the labeling depends upon the ratio
17 of dTTP to aa-dUTP, with ratios between 1:1 and 3:2 being suitable for labeling first-
18 strand yeast or mammalian cDNA. A second sample of this cDNA is subsequently
19 labeled with Fluorolink Cy3 and Cy5 Monoreactive Dye- 5 Packs (Amersham Bio-
20 sciences). The procedure of DeRisi is followed with the substitution of LnMac-mono-
21 NCS for the cyanine succinimidyl esters. In contradistinction to the findings of Randolph
22 and Waggoner (Ref. 52), the luminescence increases in proportion to the number of
23 LnMacs incorporated.

24 (g) Oligonucleotides carrying LnMac-labeled-polypeptide tails are synthesized accord-
25 ing to the procedures of EXAMPLE XII of PCT WO 01/27625 A1 (Ref. 55).

26 (h) The preferred procedure from (e), (f), and (g) will be determined by electrophoretic
27 separation of the EuMac labeled, single stranded products produced by the 3 procedures.
28 The composition of the gel depends on the size of the DNA. For human DNA produced
29 by the above procedures, 1% agarose is a reasonable starting concentration. The first gel
30 is washed twice for 10 minutes in ethanol, transferred to Gd(TTFA)₃-EtOH, incubated for
31

1 15 minutes, and dried. A control gel is also stained by this procedure. The second EuMac
2 labeled DNA-containing gel is stained according to the manufacturer's instructions with
3 diluted SYBR Gold. A control gel is also stained by this procedure.

4 The first gel containing the EuMac labeled DNA and its control gel are inserted into a
5 UVP Epi Chem II Darkroom and are illuminated with the long UV (ca. 365 nm) bulb and
6 the Eu(III) emission is detected at 619 nm. The second gel containing the EuMac labeled
7 DNA and its control gel are inserted into a UVP Epi Chem II Darkroom and are illumi-
8 nated at 254 nm and the SYBR Gold emission is detected through a 537 nm filter. Both
9 pairs of digital images of the EuMac-labeled DNA containing gels and control gels where
10 no nucleic acid has been applied are acquired with the Retiga-1350 EX camera. The
11 intensity of each emission band or area is measured with Fovea PhotoShop plug-in where
12 "feature region" is available. The integrated optical density (IOD), which is the integral
13 of the linear measurements and thus is a measurement of the total luminescence and
14 autofluorescence emission is calculated. The ratios of the emissions from the individual
15 bands in the EuMac and SYBR Gold gels are determined. The protocol with the highest
16 ratio that produces a DNA that is still capable of specific hybridization is selected.

17 EXAMPLE XXXV

18 Validation of Comparative Genomic Hybridization Techniques

19 (a) Two types of hybridizations experiments are performed. The first set of experiments
20 is intended to determine if the different labels affect the degree of DNA hybridization.
21 For these measurements, two DNA specimens are compared. These specimens could be
22 male and female DNA specimens or malignant and normal DNA specimens or other sim-
23 ilar pairs. Each of the two specimens is split into four aliquots. For two of the aliquots,
24 each DNA specimen is labeled with a different one of the LnMacs. For the other two ali-
25 quots, each DNA specimen is labeled with a different one of the cyanine or other control
26 fluorochrome pair. For instance, the EuMac-labeled male-DNA is co-hybridized with the
27 TbMac-labeled female-DNA and the EuMac-labeled female-DNA is co-hybridized with
28 the TbMac-labeled male-DNA. For these studies, the two ratios of the red and blue emis-
29 sions obtained from the individual DNA spots should be inversely related and when mul-
30 tiplied together should yield one. The average of the products of these two ratios,
31 obtained from all of the individual DNA spots on the arrays, will be calculated from the

1 results obtained from the pair of co-hybridization experiments performed with the Ln-
2 labeled-DNAs and the pair of co-hybridization experiments performed Cy-labeled-
3 DNAs. Since the LnMacs are virtually chemically identical and are isomorphous, their
4 ratio is found to be closer to one.

5 (b) The second set of experiments is intended to detect selective binding of labels to spe-
6 cific DNA sequences. This again involves DNA samples that have been labeled with both
7 LnMacs and both cyanine dyes. However, only one of the DNA samples is used for this
8 series. For instance, two Ln-labeled female DNA samples are co-hybridized and the two
9 Cy-labeled female DNA samples are co-hybridized. For these studies, the ratios of the red
10 to the blue emissions obtained from the individual spots should be identical for each co-
11 hybridization experiment. The standard deviation of the ratios from all of the DNA spots
12 is an indication of selective binding to specific gene sequences and the effects of back-
13 ground fluorescence. The standard deviation of the LnMac-labels is found to be lower
14 than that of the Cy-labels.

15 (c) These experiments are repeated with the substitution of a flashlamp or other light-
16 source for the standard (Hg and/or Xe) short arc lamp. If PDCA or other energy transfer
17 donor with a similar excitation different from 350-370 nm is employed, the light source
18 must be capable of producing pulsed light in the region of the excitation maximum. In the
19 case of PCDA, 280 nm light must be provided by the flashlamp and the camera must be
20 capable of time-gating and summing the images produced by multiple flashes.

21 EXAMPLE XXXVI

22 Simultaneous use of Lanthanide Labels as Secondary Reagents for 23 Comparative Genomic Hybridization Measurements

24 In this Example, methods of this invention to analyze genomes by Comparative Genomic
25 Hybridization (CGH) are exemplified by employing two luminescent species, each attached to
26 a secondary reagent. This procedure is based on US Patent 5,976,790. Pinkel et al (Ref. 41)
27 and Kallioniemi et al. (Ref. 46), which describe the following steps for CGH:
28

29 1. Removal of Repetitive Sequences and/or Disabling the Hybridization Capacity of Repeti-
30 tive Sequences.
31

1 2. Labeling the Nucleic Acid Fragments of the Subject Nucleic Acids.

2 3. In Situ Hybridization.

3
4 Pinkel et al. 1999 (Ref. 41) summarize In Situ Hybridization as: "Generally in situ hybrid-
5 ization comprises the following major steps: (1) fixation of tissue or biological structure to be
6 examined, (2) prehybridization treatment of the biological structure to increase accessibility
7 of target DNA, and to reduce nonspecific binding, (3) hybridization of the mixture of nucleic
8 acids to the nucleic acid in the biological structure or tissue; (4) posthybridization washes to
9 remove nucleic acid fragments not bound in the hybridization and (5) detection of the hybrid-
10 ized nucleic acid fragments."

11 These Authors state that their present technique is limited: "At the current stage of devel-
12 opment of CGH, sensitivity is primarily limited by the granularity of the hybridization signals
13 in the metaphase chromosomes. Further improvements in sensitivity will be achieved by opti-
14 mization of the probe concentration and labeling, and by the averaging of the green-to-red flu-
15 orescence ratios from several metaphase spreads." An indirect labeling procedure is described
16 below.

17 A. Materials

18 (a) The SmMac-Streptavidin Conjugate, prepared according to EXAMPLE XXVII.

19 (a) The TbMac-Streptavidin Conjugate, prepared according to EXAMPLE VIII with the
20 substitution of the TbMac-mono-NCS for the EuMac-mono-NCS.

21
22 (b) The EuMac-anti-digoxigenin, prepared by the procedures described in EXAMPLE
23 XVI with the replacement of the anti-5-BrdU by anti-digoxigenin (SIGMA #D 8156).

24 (c) DAPI of the Most Commonly Used Materials.

25
26 (d) DAPI solution, 10 μ M DAPI solution in TBS-Azide, pH 7.4.

27 (e) The Gd Rinse Buffer of EXAMPLE XIX.

28
29 (f) The Gd(TTFA)₃-EtOH of EXAMPLE V.

30 (g) The Clearium Mounting Medium of the Most Commonly Used Materials.

31

1 (h) CytoVision (Applied Imaging, San Jose, CA).

2 (i) All other materials are as described in US Patent 5,976,790.

3
4 B. Procedure

5 (a) Steps a through h of the procedures of EXAMPLE XX of US Patent 6,340,744 are
6 followed with the substitution of SmMac-Streptavidin for SmMac-Avidin.

7
8 (b) The chromosomes are incubated with 50 μ L of the 10 μ M DAPI solution for 5 min.

9 (c) The DAPI stained chromosomes are rinsed with TBS-Azide three times.

10 (d) The chromosomes are then rinsed twice with 50 μ L ethanol and air dried.

11 (e) Two drops of Gd(TTFA)₃-EtOH are applied and allowed to dry.

12 (f) The slides are rinsed twice with ethanol, removing excess liquid each time.

13 (g) Thirty μ L Clearium Mounting Medium is pipetted onto the chromosome and cell
14 area, making sure all of the chromosomes and cells are covered.

15 (h) The solvent is removed from the Clearium by mild heat generated with a heat gun.

16 (i) The chromosomes and cells are observed with a CytoVision or similar arc illuminated
17 automated fluorescence microscope under 365 nm excitation provided by continuous illu-
18 mination with a 100 watt mercury-xenon arc. The light passes through a UV DAPI cube,
19 which does not include an emission filter. Three removable band-pass emission filters,
20 each of which is blocking for the other two, are located above the cube. The transmission
21 of the first filter is centered at 619 nm and the bandwidth is approximately 10 nm at half
22 maximum. The transmission of the second filter has half maximum cut-off points at 635
23 and 660 nm, and thus includes as much of the SmMac emission as possible while block-
24 ing the radiation emitted by the EuMac and all radiation below 635 nm. The third filter is
25 a standard DAPI 450 nm emission filter (Omega 450DF65).
26

27 (j) Alternatively, one set of images is obtained with each of the 3 emission filters. All
28 images are obtained with the flashlamp flashed at approximately 40 pulses per second.
29
30
31

1 The EuMac and SmMac images are obtained after a total delay of approximately 30 μ sec.
2 The DAPI images are obtained without any delay. Two sets of control (camera noise)
3 images with the emission totally blocked are obtained. One set is obtained without any
4 delay and the other with the same delay as that employed for the lanthanide macrocycles.

5 (k) The images obtained from each set of multiple individual flashes are summed, ana-
6 lyzed, corrected for the camera noise background and the spatial nonuniformity of the
7 excitation light on the slide, and converted to a format, such as JPEG 2000, which is suit-
8 able for display with conventional computer software.

9
10 (l) The ratio of the corrected summed values of the pixels from the SmMac and EuMac
11 images is calculated and then analyzed as described by Pinkel et al. 1999 (Ref. 41).

12 (m) Alternatively, the procedures described above can be modified by to produce hybrids
13 with arrays consisting of DNA oligomers, such as those described in EXAMPLE
14 XXXIII.

15
16 (n) Alternatively, the procedures described above can be modified by replacing the
17 SmMac-Streptavidin conjugate with the TbMac-Streptavidin and the emission filter for
18 the SmMac by the emission filter for the TbMac and ultraviolet excitation optics of
19 EXAMPLE XV and the methanolic solutions of EXAMPLE XIII, which are optimized
20 employing the procedures of EXAMPLE XIV.

21 (o) Alternatively, the hybridizations could be validated by the procedures of EXAMPLE
22 XXXV.

23
24 (p) The procedures employing the optimum formulation of the unitary luminescence
25 enhancing solution with the optimum pair of energy transfer acceptor lanthanide(III) ions
26 results in chromosome preparations with minimal background and higher signal to noise
27 ratios compared to preparations with conventional fluorochromes and if analyzed by the
28 procedures of EXAMPLE XXXV are found to be superior to the preparations with con-
29 ventional fluorochromes.

30 (q) The procedure described in this example has the further advantage of simplifying the
31 instrumentation by requiring only one excitation system, which by providing the same

intensity and pattern of illumination to the sample and reference specimens increases the accuracy of ratiometric measurements, and a single dichroic mirror for three measurements. In addition, the narrow bandwidths of the emissions from both lanthanides minimize spectral overlap with each other and with the DNA stain DAPI, as well as with other fluorophores. This simplification will result in both less costly instrumentation and improved accuracy in the quantitation of the DNA probes.

EXAMPLE XXXVII

Simultaneous use of Lanthanide Labeled DNA for Comparative Genomic Hybridization

A. Materials

(a) The EuMac-5-deoxyuridine (Formula VIII) of EXAMPLE XXI of US Patent 6,340,744.

(b) The SmMac-5-deoxyuridine of EXAMPLE XXI of US Patent 6,340,744 or the TbMac-5-deoxyuridine of EXAMPLE XXXIV.

(c) 50 mmol (6 g) of TRIS of the Most Commonly Used Materials and 1 g of Tergitol, obtained from Sigma-Aldrich, St. Louis, MO, Product No. NP-40, are added to 1 L of water and the solution is adjusted to pH 8.0 with hydrochloric acid (TRIS-NP40, pH 8.0).

(d) The Gd Rinse Buffer of EXAMPLE XIX.

(e) The Gd(TTFA)₃-EtOH of EXAMPLE V.

B. Procedure

The procedure of Bastian et al. (Ref. 47), as described in EXAMPLE XXII of US Patent 6,340,744, is followed.

(a) The procedures of US Patent 6,340,744, EXAMPLE XXII, Step 1. DNA Isolation (a through d) are followed.

(b) The procedures of US Patent 6,340,744, EXAMPLE XXII, Step 2. Comparative Genomic Hybridization (a through d) are followed.

1 (c) The procedures of EXAMPLE XXXVI, Steps c through k, are followed.

2
3 (d) Hybridization quality is evaluated by the signal strength, the smoothness of the sig-
4 nal distribution along the chromosome, the lack of accentuated banding, the efficient blocking
5 of the centromeres, and the absence of artifactual ratio variations. Hybridizations in which a
6 concurrent gain of chromosomes 1 p, 19, and 22 is present are considered artifact prone and
7 are not included in the analysis.

8 The procedures for preparing and hybridizing DNA in EXAMPLE XXXIII and EXAM-
9 PLE XXXIV and those described above can also be applied to fluorescence in situ hybridiza-
10 tion and chromosome painting. The EuMac and SmMac labels can be excited simultaneously
11 with DAPI and thus can replace two of the five fluorophores employed by US Patent
12 6,007,994 (1999) (Ref. 39) included by reference to combinatorially labeled oligonucleotide
13 probes. These labeled oligonucleotide probes provide sufficient combinations to permit the
14 visualization and simultaneous identification of all 22 autosomal human chromosomes and
15 the human X and Y chromosomes, or defined sub-regions thereof. Such specific labeling of
16 entire chromosomes or defined sub-regions thereof is referred to as "painting." These nucleic
17 acid probes can also be employed for combinatorial labeling of bacteria, viruses and/or lower
18 eukaryotes that may be present in a clinical or non-clinical preparation. Ward et al. (1999)
19 (Ref. 39) is included by reference. Chapter 8 of Hemmila et al. (1994) (Ref. 37), which
20 describes the use of other rare-earth complexes for similar purposes, is also included by refer-
21 ence.

22 (e) Alternatively the procedures described above can be modified by to produce hybrids
23 with arrays consisting of DNA oligomers, such as those described in EXAMPLE
24 XXXIII.

25 (f) Alternatively, the procedures described above can be modified by replacing the
26 SmMac labeled DNA with TbMac labeled DNA and the emission filter for the SmMac by
27 the emission filter for the TbMac and ultraviolet excitation optics of EXAMPLE XV and
28 the unitary luminescence enhancing methanolic solutions of EXAMPLE XIII, which are
29 optimized employing the procedures of EXAMPLE XIV.

30 (g) Alternatively, the hybridizations could be validated by the procedures of EXAMPLE
31

1 XXXV.

2
3 (h) The procedures employing the optimum formulation of the unitary luminescence
4 enhancing solution with the optimum pair of energy transfer acceptor lanthanide(III) ions
5 results in chromosome preparations with minimal background and higher signal to noise
6 ratios compared to preparations with conventional fluorochromes and if analyzed by the
7 procedures of EXAMPLE XXXV are found to be superior to the preparations with con-
8 ventional fluorochromes.

9 (i) The procedure described in this example has the further advantage of simplifying the
10 instrumentation by requiring only one excitation system, which by providing the same
11 intensity and pattern of illumination to the sample and reference specimens increases the
12 accuracy of ratiometric measurements, and a single dichroic mirror for three measure-
13 ments. In addition, the narrow bandwidths of the emissions from both lanthanides mini-
14 mize spectral overlap with each other and with the DNA stain DAPI, as well as with other
15 fluorophores. This simplification will result in both less costly instrumentation and
16 improved accuracy in the quantitation of the DNA probes

17 EXAMPLE XXXVIII

18 Simultaneous Use of Lanthanide Labeled DNA for Comparative
19 Genomic Hybridization on Nucleic Acid Arrays

20
21 A general description of the procedures for comparative genomic hybridization was given
22 in EXAMPLE XXXIX. The procedures described below are exemplary. Alternatively, the ref-
23 erenced CGH procedures of EXAMPLE XXXIII can be followed.

24 A. Materials

25 (a) The EuMac-5-deoxyuridine triphosphate (EuMac-d-UTP) (Formula V) of EXAM-
26 PLE XXI of US Patent 6,340,744.

27
28 (b) The SmMac-5-deoxyuridine triphosphate (SmMac-d-UTP) of EXAMPLE XXI of
29 US Patent 6,340,744.

30 (c) The procedure of EXAMPLE XXI of US Patent 6,340,744 is repeated with the
31

1 replacement of the europium(III) by terbium(III) to produce TbMac-5-deoxyuridine
2 triphosphate (TbMac-d-UTP).

3
4 (d) The Gd Rinse Buffer of EXAMPLE XIX.

5 (e) The Gd(TTFA)₃-EtOH of EXAMPLE V.

6
7 (f) 1 Mb Human BAC Arrays with 2,632 BAC clones spotted on the array (Genome-
8 Chip™ V1.2, Spectral Genomics, Houston, TX).

9 (g) One male and one female preparation of the human LnMac-labeled-cDNA of
10 EXAMPLE XXXIV. Each of these preparations consists of two aliquots. One aliquot is
11 labeled with the EuMac and the other is labeled with the TbMac. These will be referred to
12 as LnMac-labeled-DNA(s).

13 (h) Sonicator with microcup horn: Ultra-sonic processor model (Sonics & Materials,
14 Inc., Newtown, CT, model VC-130).

15
16 (i) Human Genomic DNA (Promega, Madison WI, Female Catalog No. G1521; Male
17 Catalog No. G1471).

18 (j) DNA Clean and Concentrator™-5 (Zymo Research, Orange, CA, Catalog No.
19 D4005).

20
21 (k) BioPrime DNA Labeling Kit (Invitrogen, Carlsbad, CA, Catalog No. 18094-011).

22 (l) Cy3-dCTP & Cy5-dCTP (Perkin Elmer Catalog No. NEL 576-577).

23
24 (m) 0.5 M EDTA, pH 8.0.

25 (n) 5.0 M NaCl.

26
27 (o) Isopropanol.

28 (p) 70% Ethanol.

29
30 (q) The Clearium Mounting Medium of the Most Commonly Used Materials.

31

1 (r) Spectral Hybridization Buffer I (Spectral Genomics, Catalog No. KTHB1-1000H).

2 (s) Spectral HYB Buffer II (Spectral Genomics, Catalog No. KTHB2-1000H).

3 (t) Spectral Labeling Buffer (Spectral Genomics, Catalog No. KTLBRP-1000H).

4 (u) Sterile DNase/RNase-free water (Spectral Genomics, Catalog No. KTSWH-1000H).

5 (v) 2x SSC is an aqueous solution that contains per liter: 0.3 mol NaCl and 0.03 mol
6 sodium citrate.

7 (w) Sodium dodecyl sulfate (SDS) (Sigma, Catalog No. L4390).

8 (x) 2X SSC-0.5% SDS is 2x SSC with the addition of 5.0 g/L of SDS.

9 (y) Formamide, Molecular Biology Grade (Calbiochem, San Diego, CA, Catalog No.
10 344206).

11 (z) Filter paper Whatman 1001 (Fisher Scientific, Catalog No. 09-805-1A).

12 (aa) Rexyn I-300 Mixed bed, ion exchange resin (Fisher Scientific, Catalog No. R208-
13 500).

14 (ab) 2X SSC-50% deionized formamide is a one-to-one mixture of 2X SSC and deion-
15 ized formamide. The formamide is deionized by the addition of 1 g of mixed-bed, ion
16 exchange resin for every 10 ml of formamide, and stirring for 30 to 60 min at room tem-
17 perature. The resin is then removed by filtration through Whatman No. 1001 filter paper,
18 dispensed into units of use, and stored at -20°C.

19 (ac) Igepal (CA-630), octylphenyl-polyethylene glycol (Sigma, Catalog No. I8896).

20 (ad) 2X SSC-0.1% Igepal (CA-630) is 2x SSC with the addition of 1 g/L of Igepal.

21 (ae) 22 X 60 mm cover slip.

22 (af) Heat Block: Digital Dry-Bath Incubator (Fisher Scientific, Fisher Isotemp* Catalog
23 No. 125D).

(ag) Kapak* Fuji Impulse* FS-315 Shop Sealer (Fisher Scientific, Catalog No. 01-812-71, Kapak Corporation Catalog No.:FS315).

(ah) Doubly Distilled Water.

(ai) Rocking Platform Incubator: Shake 'N' Bake Hybridization Oven (Boekel Scientific, Feasterville, PA, Model 136400).

(aj) GenoSensor Reader System (Vysis, Downers Grove, IL, model No. 30-145200.

(ak) Tank of high purity nitrogen gas.

(al) 1.5 ml Eppendorf tubes with locking caps.

(am) SpectralWare™ BAC Array Analysis Software (Spectral Genomics).

(an) Hybridization Chamber (Corning Costar, No.:2551; Fisher Scientific, Catalog No. 07-200-271).

(ao) Kapak Heat-Sealable Pouch (Fisher Scientific, 01-812-25A).

B. Procedure

(a) The human male and female DNA samples prepared in step (d) of the procedures of EXAMPLE XXXIV are labeled with Cy3 and Cy5 by the procedures described in Step 2: Differentially label DNA with Cy3-dCTP and Cy5-dCTP (Ref. 57). These will be referred to as Cy-labeled-DNA(s).

(b) The LnMac-labeled-DNA and Cy-labeled DNA samples are tested by agarose gel electrophoresis as described in Ref. 57; and the size of the majority of the labeled DNA fragments prior to denaturation is found to be in the range of 100-500 base pairs.

(c) Enzymatic activity is stopped by the addition of 0.5 M EDTA, pH 8.0 and heating at 72°C for 10 min (Ref. 57).

(d) The samples are cooled on ice to before proceeding with hybridization, or stored at – 20°C until required (Ref. 57).

(e) One or more pairs DNA samples, where one member of the pair is labeled with a first LnMac and the other labeled with a second LnMac, are mixed. This can be accompanied by one or more control experiments where a pair of DNA samples, one of which is labeled with a first cyanine dye and the other is labeled with a second cyanine dye, are mixed. For the purposes of clarity, the description of the rest of the process of comparative genetic hybridization will be limited to one pair of LnMac-labeled-DNA samples. The DNA preparation procedures of Ref. 57 are followed. For this description the volume of each of the labeled DNA samples will be 110 μ L. All Spectral Hybridization Buffers are stored at -20°C until needed. The DNA is precipitated by the sequential addition of 45 μ L of Spectral Hybridization Buffer I, 12.9 μ L of 5.0 M NaCL, and 130 μ L of isopropanol. The contents are mixed at each step with a vortex mixer. The mixture is briefly centrifuged and incubated in the dark at room temperature for 20 min. The supernatant is carefully removed from the DNA after centrifugation at greater than 10,000 g for 20 min. For the LnMacs, the precipitate is visually inspected under ultraviolet light. Visible light is sufficient for cyanine dyes. The pellets are rinsed by the addition of 500 μ L of 70% ethanol followed by centrifugation and subsequent removal of as much of the supernatant as possible. The pellets are air-dried for 10 min in the dark at room temperature and can be stored at 20°C .

(f) The DNA hybridization procedures of Ref. 57 are followed. The sample is first prepared for denaturation, as follows. Sterile DNase/RNase-free water (10 μ L) is added to the DNA pellets, followed by a 10 sec centrifugation to collect the sample, incubation for 10 min in the dark at room temperature, checking that the sample has been suspended, addition of 30 μ L of Spectral Hybridization Buffer II, and mixing the sample well by pipetting. The DNA is then denatured to single strands by incubation in a heat block at 72°C for to min. This is immediately followed by cooling in an ice-water slurry for 5 min, to prevent renaturation. The sample is re-collected by a brief centrifugation and then incubated a 37°C for 30 min. The sample is pipetted as a line of liquid down the center of the Human BAC Array slide, which has been previously kept desiccated at room temperature. The sample is spread and protected by the application of a 22 X 60 mm cover-slip, avoiding the formation of air bubbles. The slide is then placed in a hybridization chamber, which is kept hydrated by the addition of 10 μ L of water to the wells located on both

1 sides of each chamber. The slides are kept horizontal for the rest of the hybridization pro-
2 cedure. The chamber is closed and protected from light by wrapping with aluminum foil.
3 The wrapped chamber, together with a wet paper towel which serves to prevent evapora-
4 tion, is placed in a Kapak Pouch, which is then heat sealed. The pouch is then incubated
5 at 37°C for 16 hours.

6 (g) The Post-hybridization wash procedures of Ref. 57 are followed. 1) The 2X SSC-
7 50% deionized Formamide, 2X SSC-0.1% Igepal (CA-630), and 0.2X SSC solutions are
8 heated to 50°C. 2) The Kapak Pouch is opened and the chamber is removed and opened.
9 3) The slide with its cover-slip is inserted in a Petri dish, covered with 2X SSC-0.5%
10 SDS, and the cover-slip is gently removed. The Petri dish is then inserted into a rocking
11 platform incubator, and the slide is rocked and washed for approximately 5 sec. 4) The
12 slide is transferred using a pair of forceps to a fresh Petri dish, which contains 2X SSC-
13 50% Formamide prewarmed to 50°C. The slide containing Petri dish is then incubated
14 and rocked in a rocking platform incubator for 20 min. 5) The slide is transferred using a
15 pair of forceps to a fresh Petri dish, which contains 2X SSC-0.1% Igepal prewarmed to
16 50°C. The slide containing the Petri dish is then incubated and rocked in a rocking plat-
17 form incubator for 20 min. 6) The slide is transferred using a pair of forceps to a fresh
18 Petri dish, which contains 2X SSC that had been prewarmed to 50°C. The slide contain-
19 ing Petri dish is then incubated and rocked in a rocking platform incubator for 20 min. 7)
20 The slide is washed twice at room temperature with doubly distilled water. For each
21 wash, the slide is transferred using a pair of forceps to a fresh Petri dish and then incu-
22 bated and rocked in a rocking platform incubator for 5 sec. 7) The slide is then immedi-
23 ately blow dried with a stream of nitrogen gas. It can then be protected from light by
24 storage in a desiccator that is protected from light.

25 (h) In the case of arrays to which Ln-labeled-DNA is bound, the procedures of EXAM-
26 PLE XIV are followed.

27
28 (i) Alternatively, the procedures of van Zyl, US Application 20040175717, (Ref. 37) are
29 followed with the substitution of the Ln-labeled-DNAs for the dUTP-Cy3™-labeled-
30 DNA and dUTP-Cy5™-labeled-DNA.

1 (j) Thirty μ L Clearium Mounting Medium is pipetted onto the array areas, making sure
2 that each array on the slide is completely covered.

3 (k) The solvent is removed from the Clearium by mild heat generated with a heat gun.
4

5 (l) In the case of TTFA containing unitary solutions, the arrays are analyzed with the
6 GenoSensor Reader System or similar arc illuminated system. The excitation filter and
7 dichroic mirror employed in analyzing DAPI stained samples is used with the emission
8 filters of EXAMPLE XXXVI.

9 (m) In the case of PCDA containing unitary solutions, the arrays are analyzed with the
10 GenoSensor Reader System or similar arc illuminated system which includes the modifi-
11 cations of EXAMPLE XV and the Eu(III) emission filter of EXAMPLE XXXVI.

12 (n) In the case of Cy-labeled-DNAs, the manufacturer's filter settings are employed.
13

14 (o) The emissions of the individual spots on the arrays are measured and analyzed fol-
15 lowing the manufacturer's instructions and with the use of the manufacturer's software.
16

17 (p) Alternatively, The hybridizations could be validated by the procedures of EXAMPLE
18 XXXV.

19 (q) Alternatively, if the time-gated system of EXAMPLE XX is employed with if neces-
20 sary the procedures of EXAMPLE XV, the removal of the background emission from the
21 preparation including the microscope slide produces superior results for the Ln-labeled-
22 DNAs to those produced by the arc lamp. The contaminating signal produced by the Cy-
23 labeled-DNAs or DAPI is minimal. The procedures of EXAMPLE XXXV are followed.
24 The luminescence ratios obtained from cohybridization experiments with pairs of DNA
25 preparations from a male and a female or a tumor and control normal tissue from the
26 same patient in which the members of each pair of DNA preparations were labeled of
27 with each of two LnMacs result in two ratios of luminescence emissions from the two
28 LnMacs from the individual DNA spots. The first ratio is obtained when first member of
29 the pair is labeled with a first LnMac and the second member of the pair is labeled with
30 the second LnMac. The second ratio is obtained when the first member of the pair is
31 labeled with a second LnMac and the second member of the pair is labeled with the first

1 LnMac. The first ratio is inversely related to the second ratio and when the first and sec-
2 ond ratios are multiplied together the result is very close to one. This is establishes that
3 the luminescence ratios are a true measurement of the ratio of hybridization.

4 (r) The procedures employing the optimum formulation of the unitary luminescence
5 enhancing solution with the optimum pair of energy transfer acceptor lanthanide(III) ions
6 results in arrays where the individual samples (spots) have minimal background and
7 higher signal to noise ratios compared to preparations with conventional fluorochromes
8 and if analyzed by the procedures of EXAMPLE XXXV are found to be superior to the
9 preparations with conventional fluorochromes.

10
11 (s) The procedure described in this example has the further advantage of simplifying the
12 instrumentation by requiring only one excitation system, which by providing the same
13 intensity and pattern of illumination to the sample and reference specimens increases the
14 accuracy of ratiometric measurements, and a single dichroic mirror for three measure-
15 ments. In addition, the narrow bandwidths of the emissions from both lanthanides mini-
16 mize spectral overlap with each other and with the DNA stain DAPI, as well as with other
17 fluorophores. This simplification will result in both less costly instrumentation and
18 improved accuracy in the quantitation of the DNA probes.

19 EXAMPLE XXXIX

20 Two Photon Excitation of the EuMac Labelled Cells Dried from a 21 Gadolinium(TTFA)₃ Solution

22 A. Materials

23
24 (a) A standard glass microscope slide with EuMac-di-NCS labelled cells prepared
25 according to the procedures of EXAMPLE XIX. A very thin layer of Clearium was allowed to
26 dry.

27 B. Procedure

28
29 (a) The slides were examined with a laser scanning LSM510 NLO/Combi system Zeiss
30 confocal microscope equipped with a Coherent Mira Ti-sapphire laser and a C-Apochromat
31 40 x 1.2 N.A. water-corrected objective. The excitation was at 800 nm, and the emission

1 between 510 and 685 nm was detected. Each pixel was 0.15 by 0.15 nm and the scanning
2 dimensions were both 76.8 nm. A 90 μ m pinhole, which corresponds to one airy unit (about
3 1.1 μ m full width at half-maximum for no zoom) was used. The laser pulse width was 100 fs
4 and the pulse rate was 76 mhz (every 12 ns), which should produce about 500 pulses in 6.4
5 microsecond dwell time on the pixel. Each line was scanned four times and the result aver-
6 aged. The optical zoom was 3. The image was displayed with the Zeiss LSM5 image browser
7 and copied into Adobe Photoshop where it was transformed into grayscale and inverted.

8 (b) In spite of the minimal integration time, the image shown in Figure 18 has minimal
9 background indicating that signal to noise was excellent. Thus, it is possible to use
10 lanthanide labels with emission enhancement by a second lanthanide for two photon
11 laser scanning confocal microscopy. Since the long wavelengths used for excitation
12 are minimally scattered by biological materials, the detection of analyte-binding spe-
13 cies located significantly below the surface of the material will be possible, particu-
14 larly when red or near infrared emitting lanthanides are used. Thus, two photon
15 excitation can be applied to the examples of this patent.

ABSTRACT

Disclosed is a spectrofluorimetrically detectable luminescent composition consisting essentially of at least one energy transfer acceptor lanthanide(III) complex having an emission spectrum maximum in the range from 300 to 2000 nanometers and a luminescence-enhancing amount of at least one energy transfer donor selected from the group consisting of a fluorophore, a lumiphore, an organic compound, a salt of an organic ion, a metal ion, a metal ion complex, or a combination thereof. Such energy transfer donor enhances the luminescence of at least one energy transfer acceptor lanthanide(III) complex, with the conditions that the emission spectrum of any energy transfer donor differs from that of its energy transfer acceptor lanthanide(III) complex; and such energy transfer donor can be dissolved to form a unitary solution in a solvent having an evaporation rate at least as great as that of water.

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Brief Description fo the Drawings

- 1
- 2 Figure 1 shows inverted images of the wells of a microtiter plate.
- 3 Figure 2 shows inverted images of the wells of a microtiter plate.
- 4 Figure 3 shows inverted images of the wells of a microtiter plate.
- 5 Figure 4 is a graphical presentation of the ultraviolet absorption spectra of the EuMac-mono-
- 6 NCS, streptavidin, and the EuMac coupled to streptavidin.
- 7 Figure 5 is a graph of the relative emission intensity versus the concentration of streptavidin
- 8 added to the biotinylated well.
- 9 Figure 6 is a plot the concentrations of $\text{Gd}(\text{TTFA})_3$ and HTTFA vs. relative luminescence.
- 10 Figure 7 is a plot of the concentrations of $\text{Gd}(\text{TTFA})_3$, $\text{Na}(\text{TTFA})$, and their one-to-one
- 11 mixture vs. relative luminescence.
- 12 Figure 8 is a plot of the concentrations of $\text{Gd}(\text{TTFA})_3$, $\text{Na}(\text{TTFA})$, HTTFA , and their mixtures
- 13 vs. relative luminescence.
- 14 Figure 9a is a graph showing the effect of differing concentrations of $\text{Na}_2(\text{PDCA})$ on the
- 15 luminescence of two different lanthanide macrocycles.
- 16 Figure 9b is a graph showing the effect of differing concentrations of $\text{Na}_3\text{Gd}(\text{PDCA})_3$ on the
- 17 luminescence of two different lanthanide macrocycles.
- 18 Figure 10 is a graphical presentation of the ultraviolet absorption spectra of the EuMac-
- 19 mono-NCS, anti-5-BrdU, and the EuMac coupled to anti-5-BrdU.
- 20 Figure 11 is a pair of inverted images of EuMac-di-NCS stained cells. A is a 5 second
- 21 exposure; B is the summation of 1000 time-gated images, each exposed for 2 msec.
- 22 Figure 12 shows four images of a single preparation of nonapoptotic cells stained with both
- 23 EuMac-di-NCS and DAPI.
- 24 Figure 13 shows two inverted images of cells stained with SmMac-di-NCS and DAPI.
- 25 Figure 14 is an inverted image of directly stained apoptotic cells.
- 26 Figure 15 is an inverted image of EuMac-anti-5-BrdU stained cells in S phase.

- 1 Figure 16 is an inverted image of EuMac-Streptavidin stained apoptotic cells.
- 2 Figure 17 is an inverted image of EuMac-Streptavidin stained cells in S phase.
- 3 Figure 18 is an inverted image of two photon excited EuMac-di-NCS stained cells.